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GENERAL BOARD OF HEALTH.

REPORT

ON THE

SUPPLY OF WATER

TO

THE METROPOLIS.

APPENDIX No. III.

REPORT AND EVIDENCE—MEDICAL, CHEMICAL,
GEOLOGICAL, AND MISCELLANEOUS.

Presented to both Houses of Parliament by Command of Her Majesty.



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REPORTS AND EVIDENCE.

MEDICAL.

Dr. Sutherland's Report.

MY LORDS AND GENTLEMEN,

IN compliance with instructions received from the General Board of Health, I have made a series of inquiries in regard to the sanitary and economic advantages of soft water supplies for domestic and manufacturing purposes, in a number of towns both in Lancashire and Scotland, which were formerly supplied with hard water from rivers and pump-wells, but have recently been furnished with soft water from gathering-grounds and other sources.

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The objects of my inquiry were not of a chemical nature, but were rather directed to ascertain from the people themselves, and from medical men, manufacturers, brewers, and other well-informed parties, what perceptible advantages had followed from the use of waters which chemistry had previously pointed out as likely to be more wholesome and cheaper than those previously in use. While thus engaged, facts of a very important nature in regard to the whole question of water-supply were brought under my notice, and I was directed by the General Board of Health to extend the inquiry, so as to comprehend these particulars also, and I now beg respectfully to lay before you the results of the whole investigation.

Economic Advantages of Soft Water.—I made inquiries on this subject in the towns I visited, both in England and Scotland; and I found that all parties, without exception, were unanimously of opinion, that very great economy had been effected by the introduction of soft water: evidence to this effect was given by engineers, manufacturers, bleachers, and brewers, while similar testimony was offered by persons using water only for domestic purposes. I select the following examples because the introduction of the soft water having lately taken place, it was more easy for the people to institute a comparison.

The experience of the town of Stockport is valuable, as affording an example of the use of two kinds of water, one of hardness of $16\frac{1}{2}^{\circ}$, or about that of the Thames water, and the other of $3\frac{1}{2}^{\circ}$, or about the amount of hardness of supplies proposed to be collected from gathering-grounds. Both are supplied by the water-works Company, the harder water derived from springs in the new red sandstone, being known as the lower level water, and the softer supply as the *higher level water*. The following are notes of evidence obtained from Mr. John Lawton, waterman to the Company:—

“All the consumers like the higher level water better than the lower level water, because the higher level water is the softest.” The consumers “want it for tea, and for washing, it makes much better tea, it uses less tea, it uses decidedly less soap. It is cheaper for washing, and there is less labour attending it. It is preferred by the brewers, because it brews better ale. The soft water does not corrode boilers. At large tea parties the soft water is used by preference, because it makes tea cheaper and better.”

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Being asked, "What is the reason people pay for your water, when they can get a supply from their own wells without paying for it?" He replies, "For the reasons I have already given. These give the universal opinions of the people, so much so that the Company has determined to supply all the districts with soft water on account of its being preferred."

John Manchester, a bleacher in Stockport, gives evidence as to the superior economic value of the soft water supply. He says, "Where we should use 50 lb. of alkali with hard water, we use 45 lb. with soft. Hard water takes more alkali and soap, to produce the same colour, than soft water does. The saving of soap is still more in proportion."

In reply to the question, "What is your experience with regard to the use of hard and soft water for calico printing?" he says, "Soft water takes decidedly less drugs to produce the same colours."

Another witness, Mrs. Unsworth, of the Mersey Inn, Stockport, stated that there was an old well in the yard of the house, from which water was drawn by a steam-engine for household use, but after having gone to this expense, it was thought better to take the Company's water, on account of its softness. She states that it brews better ale than the well-water, and also makes better tea, and uses less soap in washing, so that it was found cheaper to use the soft water than the well-water, although the former had to be paid for.

The town of Blackburn has a water supply of from 3° to 4° of hardness, which has been extensively introduced into factories and dwelling-houses. I made personal inquiries of a number of people, as to their experience of the new supply in comparison with the water formerly in use. I found the testimony unanimous as to the superior advantages of the soft water for all culinary and domestic purposes. It was stated that it made better tea, and that it saved labour and soap in washing. A respectable chemist and druggist said that he could use no other water for making infusions, as all others were hard and extracted badly.

The following notes of evidence will show the superior value of the soft water supply in the local manufactures:—

Henry Smithies—"Is an engineer at Blackburn. Is acquainted with the comparative use of hard and soft water for boiler purposes; is acquainted with the use of the present town water for boiler purposes. The town water is very superior; it does not produce scale, which the former hard water did. The hard water crusted the boilers so thick, that the crust had to be taken out with a pick-axe: the bottoms of boilers got corroded, and the rivets got eaten off. There is no question as to the superior cheapness of soft water, because the boilers last very much longer and require fewer repairs. The saving of repairs in a boiler in use in our own works made more than the difference of the water-rent paid for the soft water."

Another witness, Henry Heywood, manager of Throstle-nest Mills, states, that he can confirm Mr. Smithies' testimony in every particular. "We had," he says, "to use the brook water for about a month in the summer of last year, and our boilers got a quantity of scale on in that time; but after we got the town's water, the scale all disappeared, and the boilers are now perfectly clear from it."

In regard to the superior advantages derived from the soft supply for brewing, William Astley, clerk to Mr. Dutton's brewery, states, "that there is good clear water to be obtained from wells on the premises, but

that the soft town water is preferred and used, because it makes better ale, and extracts the malt better."

The water supply of Warrington, although having a hardness of $8\frac{3}{4}^{\circ}$, is still much softer than the water formerly obtained from the wells of the town. Mr. Riley, secretary to the Company, states that it has been introduced into all the large breweries, and also into many public-houses brewing their own beer, although the parties have wells on their premises. The saving in tea from the use of this water has been estimated at one-third of the quantity used. It also requires much less soap in washing, and is found to be superior to the well-water for all culinary purposes.

Having been informed that very satisfactory results had been obtained in using soft water for locomotive engines, I applied to Mr. Hawkshaw, engineer to the East Lancashire Railway, for information as to his own experience on the subject.

From its local position this railway affords good means of comparison, as there is one quality of water supplied at Bolton and another at Manchester, the former being a very soft water and the latter a hard one. The following is the opinion of Mr. Hawkshaw:—"I beg to state that the water supplied by the Bolton Water Works Company has always been considered by me much superior to that obtained from the Manchester Water Works Company. Its great purity and softness tend much more to the preservation of the tubes and the interior of the boilers. From the water obtained at Bolton, there is scarcely any deposit, while from that obtained at Manchester the earthy deposit is sometimes considerable."

The town of Bolton has been supplied with a water of about 2° of hardness for a considerable number of years, but another water with a hardness of about 5° is still in use in some parts of the town. A direct experiment was made last year at the Bolton Workhouse to test the economic values of these waters, the very satisfactory results of which have been communicated to the General Board of Health.

At first sight it might appear doubtful whether so small a difference in hardness as 3° could have led to such results, but the facts have been confirmed by experience in other cases, and even the poor themselves know very well the difference of cost in washing with different qualities of water.

As an illustration of this I may state, that while examining into the subject at Paisley, I asked a woman who was washing whether she preferred town water or rain water for the purpose: she immediately gave a decided preference to rain water, and on being asked the reason, said that it used less soap and soda and required less labour than the other. Now the Paisley water happens to be one of the softest in the kingdom, having a hardness of only about 2° .

It appears to be something like a positive injustice to give the poor no alternative between want of cleanliness and the labour and expense involved in washing with water of from 12° to 16° of hardness, where a softer supply might be attainable, and yet this state of things exists in not a few of our largest cities and towns.

I need hardly multiply opinions or examples; suffice it to say that those economic advantages which chemistry had pointed out as likely to arise from the introduction of soft water supplies, have been amply realized in practice.

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Advantages to Health of Soft Water.—The first consideration in estimating the effects of water on the health of a town population, is obviously connected with the source and quality of the water.

In all the places I have visited, with one exception, the water has been obtained from gathering-grounds, collected into reservoirs, and thence distributed. Three of these collecting-grounds I have myself visited,—those of Gorbals, Paisley, and Stirling. The grounds of the Gorbals Company are situated upon an elevated, undulating tract of country between seven and eight miles south of Glasgow. They are chiefly under pasture, a portion only being under cultivation, and tile-drained. The soil was said to be from 18 inches to 2 or more feet in thickness, and to rest on till, which in its turn rests on green-stone. Sections showed the water proceeding from the upper surface of the till, after having drained through the soil. There is a little peat on these grounds, but not much; and it was stated to me that it had been proposed at one point to cut off an area of peat by a separate drainage, to convey the water from it in another direction.

The gathering-grounds of Paisley are situated between two and three miles south of the town, upon the north slope of a ridge of considerable elevation, but not so high as those of the Gorbals. The slope of the grounds is steeper, so that a large quantity of water is collected notwithstanding the porous nature of some portions of the subsoil. They are all under pasture, and have a little brushwood here and there upon the surface. The water is collected by a catch-drain, down which it flows rapidly to the reservoirs.

The Stirling gathering-grounds are situated on a lofty chain of hills to the south-west of the town at a distance of about three miles. The rock is green stone covered with a thin layer of soil, and the descent very rapid. A catch drain 1,000 yards in length collects the water from one district to the lower reservoir, and the upper reservoir is supplied by another district. The grounds are all under pasture, but there is a good deal of peat in the hollows.

The sensible qualities of the various surface waters are the following:—All are remarkably soft, and to a person accustomed to the hard water supply of London the sensation in washing is, that it can be done as well without soap in these waters, as with soap in the London water. The Stirling water was stated to have only 1° of hardness, that of Paisley about 2° , and that of Gorbals about $3\frac{1}{2}^{\circ}$. Notwithstanding the occurrence of peat on the gathering-grounds of Stirling, there is no evidence of its presence in the water. It is not filtered, and yet perfectly pellucid, except that on very close examination a few white flocculi can be detected. The water of Paisley stands next in order of clearness. It is filtered before distribution, but contains a small quantity of suspended matter which renders it not absolutely transparent. There is nothing offensive, or which apparently could not be entirely removed by a more perfect process of filtration.

The Gorbals water is a little less translucent than that of Paisley, obviously from a similar cause and susceptible of a similar remedy.

The waters of Bolton and Bury are brown in comparison with those already described, particularly the latter, which is sent into the town unfiltered, notwithstanding the complaints made to the Water Company on the subject.

It is commonly believed that the soft surface waters obtained from collecting grounds are less agreeable to drink than the hard waters raised from wells. The latter are perhaps cooler and clearer, from the depth at which they are procured, and the perfect process of filtration they naturally undergo. Both of these conditions, no doubt, influence the sensible properties of well water; but they are equally attainable in the waters of collecting grounds if due care be taken. The saline constituents of hard well waters are supposed by some people to make them peculiarly palatable; but, in the first place, these ingredients vary remarkably in different waters both in character and amount, and, in the next, the taste turns out to be an acquired one; for persons who have been accustomed to drink pure water are by no means satisfied at being obliged to use a harder supply afterwards.

In a communication received from Dr. Paton of Paisley the following passage occurs:—

“I was lately on a visit to my native place, Largs, in Ayrshire, and when there took a drink of water from a well that has always been esteemed very pure; but comparing it to the water of Paisley, I thought from taste that it was the opposite, being strongly impregnated with carbonate of lime. Upon testing it, the quantity was not great, the feeling had only arisen from the extra sensibility of my taste, being accustomed to water without any impregnation,—so that pure water is always pleasanter than hard water, even though there was no danger in the use of the latter.”

Similar testimony has been given by a number of other persons; and from my own experience I have no hesitation in stating, that these surface waters are as agreeable to drink as any river or well water with which I am acquainted, and more so than many of them.

The comparative effects of hard and soft water on the health of town populations are beginning again to attract attention in this country. These were perfectly well known in ancient times, and have continued to be recognized on the Continent. Every medical writer of eminence, from the days of Hippocrates downwards, has dwelt upon the sanitary distinctions of the two kinds of water; and whatever be the language employed, whether that of ordinary observation or of chemical nomenclature, these writers have, I believe, with but two exceptions, given their suffrages either directly in favour of soft water or of water derived from such sources as would necessitate its being soft. They have nearly all condemned the use of hard waters, especially those containing lime in combination with sulphuric acid, such as the waters of our new red sandstone, as being directly injurious to health if constantly used, and tending to produce derangements of the digestive functions, glandular obstructions, and urinary diseases. The only authoritative names on the other side, with which I am acquainted, are those of Dr. Cullen and Dr. Darwin, the latter of whom, considers the use of hard waters to be necessary, on certain physiological grounds, which have long since been proved to be untenable. I am quite aware that to assert the unhealthy nature of hard waters, may excite surprise, but I feel confident, both on the ground of experience in my own person and observation in those of others, that such is the case. This matter was discussed in a paper which I had the honour of laying before the Board some time ago. It is true, all persons do not suffer to the same extent, and that the effects must be looked for in susceptible constitutions, but where attention is once directed to the subject, the facts can hardly be overlooked afterwards. Some of our

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best medical authorities have even gone the length of recommending distilled water as a constant beverage, and the entire abandonment of the use of hard water.

In those towns where a soft water supply has been lately introduced, I found a decided conviction prevailing among the medical profession as to the sanitary advantages of such waters, merely on the ground of their softness. The evidence goes to prove that dyspeptic complaints diminish, that epidemics are less severe and less fatal, and that stone and other calculous diseases are prevented. I beg to subjoin the following statements on these points.

Dr. Leech, who is a medical practitioner in Glasgow, in the district supplied by the Gorbals Gravitation Water-works, says—

“My attention has been called to the bearing of the question of pure soft water supply on the public health. The Gorbals water is very soft and pure. The new supply has been introduced about two years; but in consequence of the bad water supply which existed before the new water was introduced, my attention as well as that of my medical brethren was directed to the question for a long time previously. The comparative value of the new soft supply over the old hard supply has been matter of discussion at the Glasgow Southern Medical Society, of which I was president two years. It was the unanimous opinion of the medical profession, that great benefits of a sanitary kind had followed in the substitution of the soft water on the principle of constant supply. It has been observed, that since this change, urinary diseases have become less frequent, especially those attended by the deposition of gravel. So far as experience has gone, my own opinion is, that dyspeptic complaints have become diminished in number. With the same reservation as to time, it is the opinion of the medical profession that fever has numerically diminished, and that the cases that occur are more amenable to treatment by the use of the soft water supply than they were with the former supply.

“During the late cholera there was a remarkable circumstance which deserves notice as compared with the epidemic of 1832. Since the former period, the population of Glasgow south of the Clyde has nearly doubled, and with this exception, and the introduction of the soft water supply, the circumstances might be considered as the same at both periods. In one district, the parish of Gorbals, the attack in 1832 was fearful, while Glasgow, north of the Clyde, also suffered severely. During the late epidemic, Gorbals parish furnished comparatively a small number of cases, while the epidemic in other parts of Glasgow was very severe. The unanimous opinion of the Medical Society was, that this comparative immunity was to be attributed to the soft water supply.”

Dr. Cunninghame, who also practises in the Gorbals district, is of the same opinion as to the sanitary advantages which have resulted from the substitution of soft for hard water in this part of the city.

I received similar testimony from Mr. Wolstenholme and Mr. Robinson, surgeons practising in Bolton, where there has been for some years a soft water supply. This has been already laid before the General Board of Health.

Although the town of Stirling has only had soft water for about a year, sanitary results have already shown themselves, and for this fact I have the authority of Dr. Forrest, of that town.

In regard to the sanitary advantages of the soft water supply at Paisley, Dr. Paton, makes the following remarks. After stating that Paisley was originally supplied with well-water, containing many mineral substances, particularly carbonate of lime and iron, for which the inhabitants substituted river water, he goes on to say:—

“In the year 1838 the water was introduced into the town by gravitation. It is a very pure quality, containing little, if any, mineral impregnation, being mostly rain-water collected over hills of whinstone, or clay porphyry. The pipes being always kept full, there is very little decomposition within them, and a

constant supply. Most of the inhabitants, I understand, nearly 90 per cent., are in the habit of using it. * * * I was not in town previous to the filtered river-water being used, but in the first ten years of my practice here, from 1827 to 1838, cases of calculous disorders were very numerous; the last ten years I have seen few or none, unless a few old cases previously affected, or in parts not accessible to the water of the Company, and a few from some of the chalk counties of England. With regard to the time previous to the introduction of the filtered river-water, which must have been about 1804 or 1805, I can communicate nothing of my own knowledge, but from frequent conversations with my partner, the late Dr. White, of this place, who had been upwards of 50 years in practice when I joined him, I was given to understand that the cases of stone were very numerous. The same thing was often mentioned by other old practitioners. They also mentioned the rapid diminution of them after the river-water came to be used in part, and now there is not a single case of calculous disease except those previously mentioned."

In another communication, Dr. Paton mentions several cases of renal calculi which had come under his care from distant towns. He states that these cases had had no return of the complaint for the last six months, except a slight attack in one which did not confine the patient to bed. This circumstance Dr. Paton attributes to the use of the soft water. He also says:—

"I may mention that since the 1st July 1846, I have attended 4,262 paupers for the Abbey parish, and among that number there has only been one case of calculous disorder. The boy was from Ireland, and had suffered long before coming to this country. I have had conversation with several of the surgeons here, and they all concur in the opinions expressed in my former letter to the General Board of Health, that since the introduction of the soft water by gravitation, there are almost no cases of calculous disorders, either renal or vesical."

In illustration of the benefits of soft water in diminishing epidemics, Dr. Paton states from a knowledge of the sources of the water supply in affected districts in the west of Scotland, that—

"Cholera appears, during this last and former attack, to have been more severe in those places where the water is obtained from calcareous wells, or where it is impregnated with other mineral matters, than in those places where it issued from wells over trap, or where it flows over a rocky soil of that nature. * * * I may mention that in Charleston, a district of Paisley, standing higher and possessing purer air than most of the town, and containing about 4,500 inhabitants, mostly supplied with water from wells and not from the Company, cholera made its most severe attack, hardly missing a family, except a few who were supplied with pure water. * * * When cholera prevailed, I attended many cases of diarrhoea, particularly in parts of the town supplied with wells."

A similar observation was made and published by the Local Board of Health in Paisley, in regard to developed cholera. In the same report they showed that *cæteris paribus* those parts of the town in which the gravitation water was used, were much less affected with fever than the districts supplied by wells. In regard to this report, Dr. Paton says:—

"You will perceive that where pure water has been supplied, there have been only 346 cases of fever during twelve months, and where it has not, the numbers have been 502. This difference is not so marked, but when it is considered that the larger number comes from one-tenth of the inhabitants, and the smaller from the remainder, it is then fully seen what is the value of the pure water. * * * My observations on the water of other places, as compared with this, lead me to the conclusion that no expense ought to be spared to supply towns with pure water, and that without any mineral impregnation. This, however, can only be accomplished by collecting the water from high grounds formed of trap or primitive rocks, and not from soils impregnated with lime, &c. For such a place as London, though the water was brought from Wales, the ultimate advantages would more than counterbalance all the trouble and expense, but some place perhaps could be found nearer, and of sufficient height to give a constant supply."

Such is the experience which has been obtained in towns supplied

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with soft water, and although the surface over which the observations have been made has not, from the nature of the case, been so extensive as might have been desired, they nevertheless, so far as they go, unquestionably confirm the experience of all preceding ages and countries. I cannot therefore but express my conviction that in all towns where it may be found necessary to obtain a new source of supply, this evidence as to the peculiar advantages of soft water in regard to health should apart from the well known economic value of such water, exercise great influence in determining the selection.

Public opinion, founded on experience, is rapidly progressing towards sound views on this important subject. All the old forms of water-supply are gradually being superseded; the use of wells has given way before the introduction of supplies from rivers, and even where considerable expense has been incurred in erecting suitable works for pumping river water to a proper height, it has been discovered that there are purer, better, and cheaper sources than rivers. I have been informed that the City of Glasgow Water Company would willingly introduce a supply of pure soft water on the gravitation principle, if they had adequate securities for receiving a return for their capital, which, however the present state of the law renders very doubtful. Surface supplies are universally preferred in Lancashire to those obtainable from rivers or wells. The inhabitants of Dumfries were divided in opinion, as to whether a supply should be obtained from the river close to their doors, or from a distant lake which yields pure soft water; but after a full consideration, a decision has been come to in favour of the latter source. All the more recent water supplies in Scotland are derived from lakes or gathering grounds, and to all appearance every town in that part of the country will in a few years have similar advantages conferred on it.*

* After having visited the collecting grounds from which are derived the water supplies for part of Glasgow, Paisley, and Stirling, I was directed by the General Board of Health to inspect that portion of the proposed gathering-grounds for the metropolis, situated in the neighbourhood of Farnham, and from a few acres of which that town at present receives its supply of water, with the view of comparing the apparent capabilities of the different sources of yielding waters of good and wholesome character. I have already stated, that the collecting-grounds for the Scotch towns are in elevated situations, and consist of insoluble and impervious mountain masses, from the surface of which the rainfall is drawn off as rapidly as possible by suitable catch-drains. The hills in the neighbourhood of Farnham, although rising to a considerable altitude in some parts, are formed of silicious sand and gravel, covered with short herbage and, in some part, with a thin layer of peat. The surface bears unequivocal evidence, that a considerable quantity of water flows over it directly to the lower levels; but the structure of the ground, and the occurrence of springs of pure water from the hill sides, show that a process of filtration through the sand and gravel takes place at the same time. The supply for Farnham was stated to be derived by tile-draining a few acres of ground. It is received into a shallow circular well, about three feet below the surface, from whence it flows into the main. At another part of the hill a stream of water was flowing after having percolated through a considerable thickness of gravel.

Present Supply and Consumption under the Constant System.—

One special part of the inquiry connected with the sanitary advantages of increased water supply, was directed to ascertaining the precise quantity of water consumed by different classes of the community. It had been stated to the General Board of Health that the actual quantity drawn from the reservoirs for this purpose amounted to from 13 to 30 gallons and upwards per head per diem, for the whole population, in those towns where a constant supply had been provided. No one at all conversant with the habits of the working classes, or with the miserable deficiency of domestic conveniences within their dwellings, could for a moment entertain the idea that any such quantities were used by them, although there could be no reasonable doubt that the measurements of the water drawn from the reservoirs were accurately given.

I have pursued this inquiry in a number of towns, but it appears

Both these waters have been found to be remarkably soft and pure, and in this respect in every way adapted for use. So far as their physical properties are concerned, they may be safely pronounced to be superior to those of any of the waters I examined either in Scotland or Lancashire. They are perfectly transparent, and at the time I examined them contained no floculi or colouring matter. They were cold and well ærated, arising no doubt from the perfect process of filtration they undergo, and from the fact of their retaining the temperature of the gravel bed through which they pass. At one point, the water, after flowing from the hill, rested on a quantity of peat in a hollow, and became coloured, but the same water, after having flowed over a bed of pebbles for a short distance, had lost the colour entirely, and became transparent.

The collecting of water from such grounds as those which supply Farnham involves the application of a principle of extreme importance in a sanitary point of view, namely, the natural filtration of water, and the conveying it away for use as rapidly as possible after it reaches the surface. In grounds where a considerable delay takes place between the time of rainfall and the time of delivery of the water, if there be much peat on the surface, the water becomes discoloured and requires a careful process of subsidence and filtration to remove the colour; but the experiment now going on near Farnham has demonstrated this important fact, that the atmospheric water, after having passed through a natural filter composed of insoluble materials, may be collected in abundance by a simple process of tile-draining a few feet below the surface, and delivered in a state of as great purity and softness, and at the same time with more transparency and coolness than it has been yet obtained from the surface of any collecting-ground with which I am acquainted. There were some particular portions of the ground which appeared to be faulty, but these could no doubt be avoided in selecting the surface from which the water might be obtained.

I have not seen the grounds from which Aberdeen is supplied; but from accounts I have received of them, and also of the quality of the water, I see no reason to doubt that such grounds as those which supply Farnham would yield a water as suitable for domestic purposes; and that were the metropolis to receive the benefit of such water it would have a supply, to say the least of it, as good as, if not better than that of any city of ancient or modern times

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that no estimate of the actual consumption has hitherto been made, although information of this kind must be obviously of primary importance to water Companies, engineers, and the public at large. The investigation presented considerable difficulties, especially in those instances in which the supply is obtained within the houses, and this arises from the circumstance that there is no process of measurement in using the water, the practice being to fill any convenient vessel, whatever its shape or size may be, to wash hands, dishes, and sometimes clothes, in the sink, while the pipe is allowed to run, so that no estimate of the quantity can be obtained. Similar obstacles exist in the better class of houses, which are supplied with baths and water-closets; but nevertheless an approximate estimate may be arrived at in these cases, while amongst a class which constitutes more than half of the whole population in these towns, tolerably correct measurements may be obtained. I allude to those families who derive their water supply from stand-pipes.

While engaged on the subject of water supply in the Scotch towns, I obtained the assistance of parties fully conversant with the dwellings of various grades of the working classes, and such a number of examples were taken as in the opinion of those parties afforded fair average specimens from which to draw conclusions. It is a practice with the working classes in Glasgow, Paisley, and Stirling, to carry the water from the stand-pipes into their houses in vessels of a uniform size, some of them holding $1\frac{1}{2}$ gallons, and others 2 gallons. This was ascertained by direct measurement. By conversing with the people and recalling to their minds the various purposes for which they required water, there was no difficulty in learning the number of times they sent their vessels each day to be filled. It was found that the washing of clothes was performed in some instances once a-week, but in the majority once a-fortnight, and the people readily stated the quantity of water required for that special purpose. By dividing this quantity by the number of days, and adding the daily proportion to the quantity required for other purposes, the following estimates of the daily supply of each house were obtained. The people stated that the quantities given comprised all the water used for every purpose:—

DAILY HOUSEHOLD CONSUMPTION OF WATER FROM STAND-PIPES IN GLASGOW, north of the Clyde

Houses.	Inmates.	Gallons of Water used per House per Diem.	Houses.	Inmates.	Gallons of Water used per House per Diem.
1	4	4	13	12	7
2	5	4	14	3	2
3	7	$5\frac{1}{2}$	15	7	6
4	2	$4\frac{1}{2}$	16	4	3
5	3	4	17	3	$1\frac{1}{2}$
6	2	3	18	5	$4\frac{1}{2}$
7	3	$2\frac{1}{2}$	19	6	3
8	7	6	20	5	2
9	4	4	21	2	$2\frac{1}{2}$
10	3	$2\frac{1}{4}$	22	7	5
11	3	4	23	8	$7\frac{1}{2}$
12	3	2	24	6	$3\frac{3}{4}$

The total results of this table stand as follows:—

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	Number of Houses.	Number of Inmates.	Gallons of Water used per Diem.	Gallons of Water per Head per Diem.
	24	114	93½	0·82

The portion of Glasgow from which these examples have been selected has a constant and unlimited supply of water from the river Clyde by pumping, and I now proceed to give the results of a similar inquiry in that part of Glasgow south of the Clyde, which is supplied with water on the gravitation system by the Gorbals Water Works Company.

DAILY HOUSEHOLD CONSUMPTION OF WATER from STAND-PIPES in GLASGOW, south of the Clyde.

	Houses.	Inmates.	Gallons of Water per House per Diem.		Houses.	Inmates.	Gallons of Water per House per Diem.
	1	3	4		11	7	4½
	2	6	4½		12	3	4½
	3	7	6		13	3	2
	4	6	6		14	5	4½
	5	3	4½		15	4	6
	6	5	6		16	4	12
	7	5	6		17	4	5
	8	5	8		18	10	6
	9	3	6		19	4	8
	10	3	3		20	7	4½

This table gives the following results:—

	Houses.	Inmates.	Gallons per Day.	Gallons per Head per Day.
	20	97	111	1·14

The table which follows exhibits the household consumption from stand-pipes, under the system of constant supply in the town of Paisley.

	Houses.	Inmates.	Gallons of Water per House per Diem.		Houses.	Inmates.	Gallons of Water per House per Diem.
	1	3	6½		7	4	4½
	2	4	6½		8	2	2
	3	4	7		9	8	11
	4	6	7½		10	4	3
	5	4	8½		11	3	4
	6	4	9		12	8	6½

The following are the total proportions:—houses, 12; inmates, 54; gallons of water used per diem, 76; total consumption per head per diem, 1·4 gallons.

Dr.
Sutherland.

At Stirling I instituted a similar inquiry, and the result was that the quantity of water taken from stand-pipes in that town, for domestic purposes, did not exceed two gallons per head per diem.

In order to be able to form an estimate of the entire quantity of water required for the daily consumption of that class of the population supplied by stand-pipes, it was necessary to ascertain approximately the number who derived their supplies in this way. For the following estimates I am indebted to Mr. Mackain and Mr. Hodges, the managers of the water-works in Glasgow, to Mr. Holms of Paisley, and to Mr. Robertson of Stirling.

	Population supplied by Stand-pipes.	Population supplied within their Dwellings.
Glasgow, north of the Clyde . .	160,000	165,000
" south " . .	14,500	55,500
Paisley	23,690	6,000
Stirling	7,125	3,180

The estimates are formed on the assumption of a population of five to a family, which is considered a fair average; and the statement in the preceding tables, I believe to be a correct representation of the actual quantity used. I am aware that this is very much lower than is generally believed, especially when contrasted with the quantity sent into the mains per head of the population, and I was myself by no means prepared for the results which the investigation brought out. It had been so constantly affirmed that the daily supply represented the daily consumption, that I had almost arrived at the conviction, that the more moderate estimates of what could be used for domestic purposes were very much below the truth, although at the same time on considering the habits of a large proportion of the working population, I could not but feel that they did not afford very strong indications of a liberal use of this prime element of health and cleanliness.

I have heard the great discrepancy accounted for by assuming a wasteful use of the water at the stand-pipes, by washing under them; but all I can say is, that in the course of my inquiries I never met with a single such instance, and the people constantly asserted that their statements as to the total consumption were correct. However, with such an abundant waste, it is possible to be a little liberal, and I shall therefore assume the consumption at two gallons per head per day, and this amount would indicate a supply of 320,000 gallons, as being sufficient under the present system of distribution for 160,000 people in Glasgow, north of the Clyde, or nearly one-half of the entire population, provided the quantity could be delivered without waste. Some idea, however, of the extent of the latter may be formed, when it is stated that the quantity pumped into the mains for this proportion of the population, is no less than four millions of gallons a-day.

The amount required for the domestic consumption of 23,690 persons in Paisley, or about three-fourths of the consumers, would be in round numbers 48,000 gallons; while the actual quantity sent into the mains is above 450,000 gallons. Similar discrepancies will be found to exist

elsewhere, and it must be borne in mind that these occur in populations having a constant and unlimited supply of water always at their command, the only condition being that the amount required has to be carried from the stand-pipe into their houses, and that the water used be carried out, since there are no sinks or domestic convenience within this class of dwellings.

In the various districts visited, I found very clean houses even amongst the poorest members of society, but these I am sorry to say were only exceptional cases. Setting them aside, I think it may safely be stated that the proportion of water used, affords a tolerable estimate of the state of domestic cleanliness among the poor. The smaller the quantity of water said to be used, the more filthy was the dwelling; and I feel satisfied that in the vast majority of cases, the meagre supply taken from stand-pipes is rather intended for the absolute wants of nature than for anything beyond them, the labour of carriage being an insurmountable obstacle to the liberal use of water for household purposes.

There is a considerable, and I rejoice to say, an increasing class of working men's houses within which water-pipes and sinks have been introduced; and in Glasgow several dwellings of from 6*l.* to 8*l.* rent have been recently fitted up with water-closets and shower-baths. In these, and also in the middle and upper class houses, a larger quantity of water in proportion to the inmates is doubtless used. Were there no waste from the supply-pipes, the actual quantity which the inhabitants of these houses would have at their disposal, after all the people supplied by stand-pipes had received their two gallons each, would be somewhere about 47 gallons per head per diem. A moment's consideration will show that no such quantity can be used, even taking into consideration the shower and plunge-baths with which many of the houses are provided. No extra charge is made for baths, and therefore the precise number cannot be ascertained from the water company's books; but if we assume that every house in Glasgow, north of the Clyde, of from 20*l.* to 30*l.* rent is supplied with a shower-bath, there would be 3,722 of these conveniences; and if it be also assumed that every house of 30*l.* and upwards, is furnished with a plunge-bath, water would have to be accounted for as supplying 3,329 of these. I have no doubt that these figures indicate a larger number than are in daily use; while if it be even granted that they are all used, the water required would by no means correspond with the quantity which disappears from the mains.

Notwithstanding the difficulty of obtaining accurate measurements I have been able, through the kindness of parties taking an interest in the inquiry, to procure the following information in regard to a few middle class houses in Glasgow. In one such house, with 9 inmates, the consumption was about 5 gallons per head per diem. In another, with three inmates, it was under 7 gallons per head. In a third, with 6 inmates, it was about the same quantity; and, in a fourth, inhabited by a respectable working man, it was 4 gallons per head, which includes in all the cases that used for the washing of clothes, it being the usual custom in Glasgow to perform this operation at home.

The following measurements have been sent me by Mr. Robertson of Stirling:—

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Houses.	Inmates.	Gallons per House per Day.	Gallons per Head per Day.
1	7	21	3
2	5	20	4
3	5	24	$4\frac{4}{5}$
4	5	56	$11\frac{1}{5}$
5	12	50	$4\frac{2}{12}$
6	5	43	$8\frac{3}{5}$
7	6	100	$16\frac{2}{3}$
Totals	45	314	7

The average given of 7 gallons per head is too great, as it was washing-day in houses 4 and 7, which accounts for the quantities being doubled, but as this happens generally once a fortnight the additional amount must be deducted in these two cases, and a like proportion added in the others, which would give an average consumption in the better class of houses, including washing and water-closets, of little more than $5\frac{1}{2}$ gallons per head per day.

Mr. Robertson gives an instance of four families living in the same block, and having water-closets, and supplied by one large cistern. The quantity drawn in this case was 182 gallons for 17 inmates, being at the rate of about $10\frac{3}{4}$ gallons each. In this instance also it was washing-day in two of the families. In another case 7 families consisting of 31 persons, each house being also supplied with a water-closet, consumed 284 gallons a day, or about 9 gallons each.

I have made several attempts to procure measurements of the quantity of water actually used under the constant supply at Bolton and Bury, but hitherto without success. The quantity reported to be sent into the mains at Bolton is about 15 gallons per head for each consumer, and at Bury about 16 gallons per head. As there are no stand-pipes, or other means of comparison, an approximation to the actual consumption cannot be obtained, but sufficient has been stated in regard to other places to show that the quantity discharged into the mains is no criterion of that which is really drawn within the houses.*

The discussions on the water question in Liverpool have led to important measurements there. I have the authority of Mr. Newlands, the borough engineer, for stating that the result of a direct experiment as to the consumption of water for all purposes, made in a first class house, including washing, baths, and water-closets, was 7 gallons per

* Since the above has been in type, I have received the following information on the subject from Mr. Harper, Bury:—"I have had Parkinson's (of Bury), patent water meter at work, in a house of 14*l.* a-year rental. Family, seven persons. The result of one week's test is exactly 287 gallons, or 41 gallons per diem. It includes a washing-day." This accurate measurement gives $5\frac{6}{7}$ gallons per head per diem, and approximates closely to the measurements in other towns. In a cottage of 3*s.* 2*d.* a-week rent the same meter gave a consumption of 6.8 gallons per head per day, in a family of seven persons. And in another family of seven persons inhabiting a house of 50*l.* a-year rental, it showed a consumption of 6.88 gallons per head per diem. Both of these examples includes a washing-day; but the last one does not give the quantity used for a water closet which happens to be supplied with rain water.

head per diem. A like measurement was made of the supply to one of the Liverpool hospitals, and it was found to be 10 gallons per head per day; but it is only fair to state that the consumption in hospital is higher than for domestic use, on account of the large comparative quantity required for baths, and the still larger amount consumed for the continuous washing required amongst sick persons.

The Liverpool workhouse contains about 2,000 inmates, and is supplied with water-closets, baths, &c. The consumption in this house was found to be somewhat under 3 gallons per head per day.

If any reasonable allowance be made for domestic consumption, it is obvious that a prodigious waste of water must occur in some form or other. Mr. Mackain stated that the quantity pumped into the mains solely for domestic use was between 10,000,000 and 11,000,000 of gallons a-day in Glasgow north of the Clyde, which, after a large deduction for waste, would still leave 25 gallons per head of the population for actual consumption.

From the Gorbals water-works the estimated average supply is about 32 gallons per head. In Paisley it is about 20 gallons, and in Stirling 13 gallons. These are the quantities actually flowing into the mains, exclusive of the supply for public works, and all similar purposes; and yet notwithstanding the great differences in quantity, the people asserted in every case that they had as much water as they could use; in fact, the largest amount per head taken from stand-pipes was in the town of Stirling, where the absolute quantity flowing from the reservoirs is very much less than in any other instance, and it thus becomes an object of paramount importance to inquire into the causes of these discrepancies.

The very first circumstance in the inquiry which attracted my attention was the enormous and continuous waste not only from the stand-pipes, but also from water taps on stair heads, and within private houses. It was stated that there were 1,800 stand-pipes, with $\frac{3}{4}$ -inch taps, belonging to the City of Glasgow Water Company. The number in Paisley was said to be about 600, and in Glasgow, south of the Clyde, about 200. With very few exceptions those which I myself saw were leaking to a considerable degree, and I feel satisfied that in numerous cases the leakage amounted to many times the supply required for the whole neighbourhood.

Mr. Mackain informed me that he had six men always employed in attending to these common taps belonging to the Glasgow Water Company, to see that they are in good order, and that the water is not allowed to run to waste, and yet it was found impossible to prevent it.

He also stated that the people would sometimes put a nail into the tap to keep it open, and that the water is thus left running under a head pressure for days together till it is discovered. It appears, also, that in several instances the new supplies have been transmitted through the old works, and doubtless a good deal of loss arises from this circumstance. All parties were agreed that the waste of water must be very great, but I could not ascertain that any remedy had suggested itself. Thus Mr. Mackain states that no less than 3,000 gallons per minute were required to be pumped into the mains of the City of Glasgow Water-Works to keep them charged during the night.

The quantity which passes into the mains of the Gorbals Gravitation

Dr. Sutherland.^a Company was said, by the superintendent at the water-works, to be about 150 cubic feet per minute during the night hours;* and into those of the Paisley Water Company about 70 cubic feet per minute. These estimates are exclusive of the supplies for storage at the various works; and as only a very small quantity can be drawn for domestic purposes in the dead of the night, I fear they must be set down as representing approximately the loss from leakage in the services.†

Under any system of water supply it would probably be always requisite to count on a certain amount of waste from carelessness; but surely, in the present state of engineering science, it is possible to effect such improvements in the distributary apparatus as to diminish greatly, if not altogether to prevent, the loss from leakage.

Another source of waste appears to proceed partly from defective filtration of the water, and partly from the deposit of oxydes from the iron mains. These causes act in a twofold way: the body of the water is not so clear as it ought to be, and the first portions drawn from the stand-pipes and taps are always more or less muddy; so that I found the people were in the habit of allowing the water to run for a short time before taking what they required for use, and that it was also found necessary to flush the mains very frequently in order to keep them clear of deposit. There is nothing in either of these causes of waste which might not apparently be easily remedied; for in the first place, no water should be supplied which is not perfectly pellucid and free from suspended matter; and, on the other hand, it is no doubt possible to coat the inside of the mains with some substance impervious to the action of water.

My own opinion, in reference to the ultimate cause of this waste, is, that it must be attributed to the practice hitherto followed of separating the distributary apparatus from the works of water supply. The water companies have taken the steps they thought best for obtaining an abundant and pure supply, and for laying down mains to convey it to the localities where it was required; but from this point the whole distribution has been conducted pretty much at hazard. There has been no oversight exercised upon the supply-pipes or taps, which are frequently of unsuitable construction and in a bad state of repair. It is true that powers generally exist enabling the companies to enter private dwellings and inspect the services, but practically they have not been exercised, and there is, so far as I know, no legal provision for insuring the use of any improved apparatus, however excellent. It may be truly stated, that at present the large supplies furnished to the towns which I visited are required, 1st, for *waste*; 2nd, for domestic supply. A small portion of the engineering talent which has been bestowed on the works would readily discover means for reducing the waste; and I have seen nothing in the whole of the inquiry which could justify the very high estimates which have been given as to the quantity required for absolute consumption. If the public are determined that the existing form of management shall continue, there appears to be no

* More accurate inquiries on this point are being made.

† I have been informed by Mr. M'Donald, the water inspector at Liverpool, that he recently discovered a wastage in a cellar, which, on a moderate calculation, had been discharging at the rate of 42,000 gallons a-day for the last 12 or 15 months.

alternative but to submit to the loss, and to pay the very heavy local tax which it involves; but if an enlightened view of the question be entertained, and if it be really an object to obtain an abundant and cheap water supply for the poor, steps must be taken to secure the union of all portions of the works under one management, and to direct engineering talent to the improvement of the means of distribution.

The evidence adduced as to the small quantity of water taken for domestic purposes when it has to be carried, and the state of the interior of the houses, is quite sufficient to show that the system of constant supply from stand-pipes, although beneficial to a certain extent in a sanitary point of view, is by no means sufficient to effect all the improvement necessary in this direction. It is undeniable that houses into which the water had been conducted were very much cleaner than those into which it had to be carried by hand, notwithstanding that in both cases the supply was unlimited and constant. I conceive it to be indispensable to afford a constant water supply to every house. The water and soil-pipes are as much part of a house as the doors and windows; and nothing but that lamentable neglect of public duty which has delegated the important function of supplying the population of towns with one of the vital elements into the hands of private speculation could have led to the disjoining of the different parts of the same machine, thereby impairing the efficiency and increasing enormously the expense of the whole.

The evidence in the preceding pages appears to me to justify the following conclusions:—

1st. That the economic value of soft water for the supply of towns has been fully proved by experience.

2nd. That the use of soft water for all alimentary purposes is more conducive to health than that of hard water, at least among town populations.

3rd. That the estimated water supplies of towns have in many instances greatly exceeded the actual consumption.

4th. That under existing management the first and chief necessity to be provided for by water companies has been *waste* of the supply, while the domestic consumption has occupied in reality only a secondary position.

5th. That this waste originates partly in the disjunction of works which ought to be united under the same direction, and partly from defective nature of the services, and the small amount of attention which has hitherto been bestowed on their improvement.

I have the honour to be,

My Lords and Gentlemen,

Your obedient servant,

Liverpool, 22 May 1850.

JOHN SUTHERLAND.

Philip Henry Holland, Esq., Surgeon, formerly of Manchester,
examined.

Your Report on the sanitary condition of Chorlton-upon-Medlock has been read by the Commissioners; and it is, moreover, understood, that you have been led to pay special attention to the question as to the water supply for towns?—I have; I took an active part in the inquiry for an increased supply and improved method of distribu-

Mr. Holland.
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Mr. Holland.

tion of water for Manchester, and have taken great interest in the subject generally.

Where do you now reside, and with what water are you now supplied?—I reside at 74, Upper Stamford-street, Lambeth, and used to be supplied with water by the Lambeth Company. The water is, I understand, derived from the Thames near Waterloo Bridge; I now procure a supply from the Vauxhall Company. The water is taken from the Thames near Battersea, which is not quite so bad as that taken near Waterloo Bridge.

What is the usual quality of the Lambeth Company's water?—It is very hard, and so foul as to be quite unfit for drinking. It is often, nay generally, offensive, and in warm weather swarms with visible insects. Even when filtered, it is unfit for drinking, and is, as I believe, unwholesome. To render it fit to drink, I am obliged to add to it lime water, as recommended by Dr. Clark, which precipitates the chalk and much of the organic matter, and renders it less hard, and removes its unpleasant taste and smell.

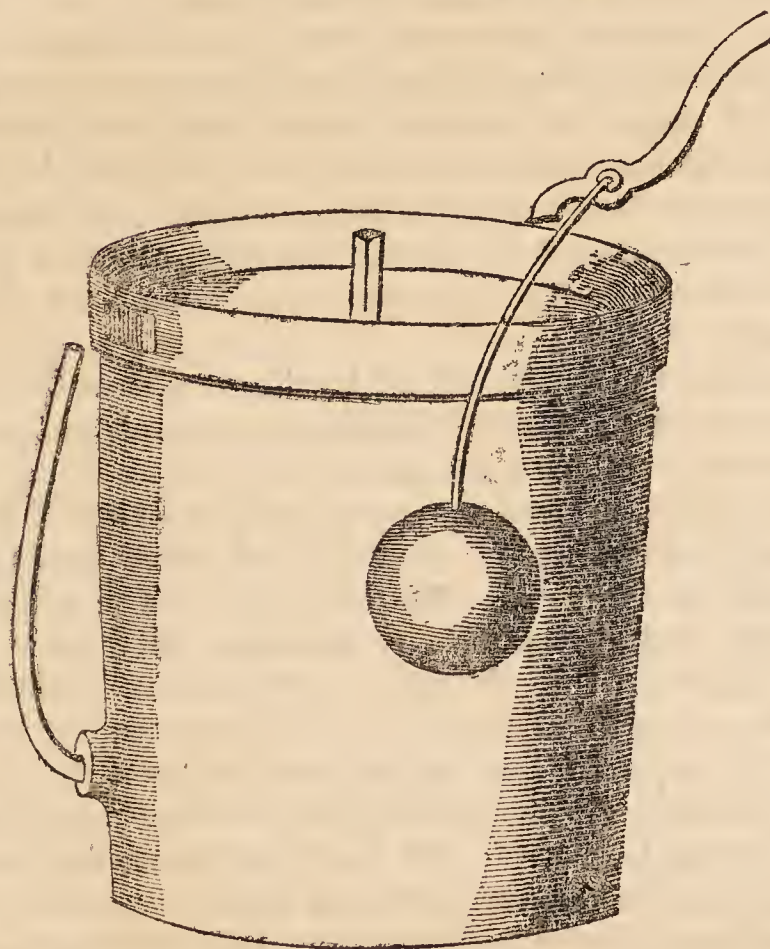
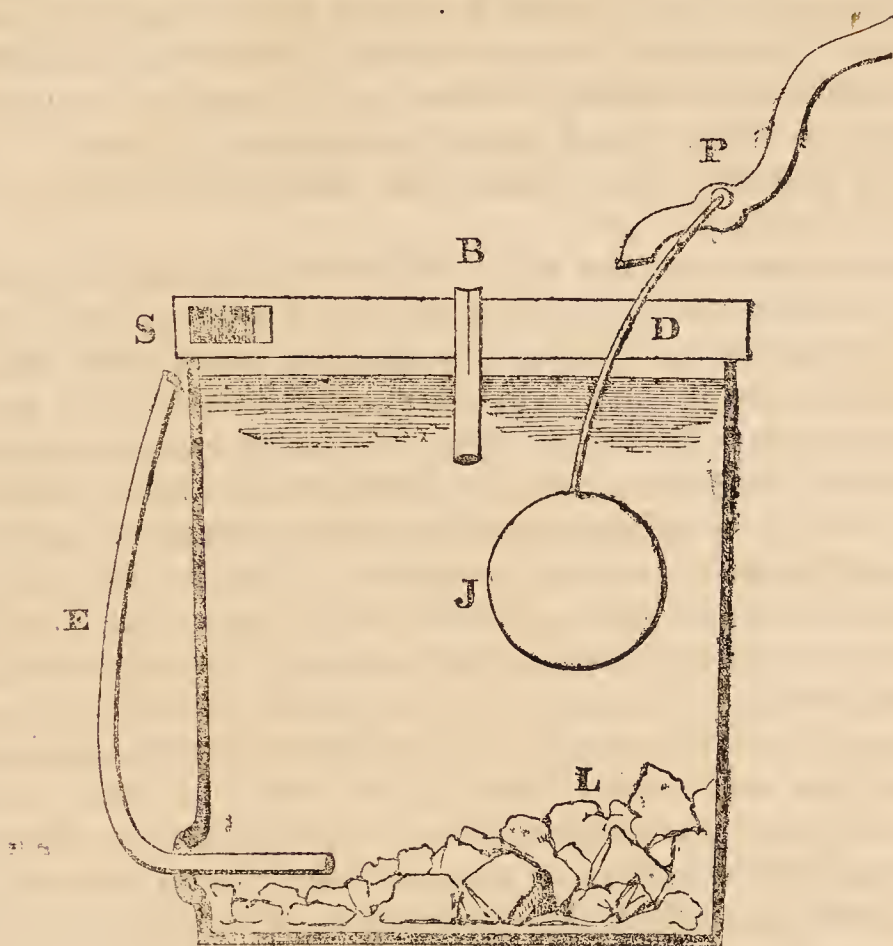
Is not this a troublesome process?—Not very, but it requires constant attention, and is apt to be neglected. It is very unjust for the Company to impose this trouble upon me; they charge an exorbitant price, and ought to supply a good article, instead of a liquid unfit for either drinking or washing with, until I do with it what the Company ought to do for me. It would increase their expenses but little to add the lime, and filter the water; but if all their customers do as I do, their total expenditure must be something considerable, and if they do not, they must suffer losses much more serious.

How do you mix the lime water?—I have two jugs, one holding 13* times as much as the other. I fill the smaller one with a saturated solution of quick lime (lime water), put this quantity into the larger one, and fill it up with the water to be purified, and mix the two together; chalk is formed by the union of the bi-carbonate of lime in the water with the quick lime added; this falls slowly to the bottom of the jug, carrying with it most of the organic impurities; the clear water is filtered for use. To avoid this trouble, or rather to ensure the regular addition of the lime, I have constructed a simple instrument which mixes the lime-water for me, and requires no attention except adding fresh lime once or twice a month.

Describe the apparatus?—It is very simple, as may be seen from this drawing. J is the lime-water jar, which is placed in the cistern, with its top just above the water line; in this I put a few pounds of quick lime, which requires renewing from time to time. On the top of the jar is a zinc dish D, into which the water from the supply-pipe runs, and is stopped when the cistern is filled. This water entering is divided into two portions; one thirteenth part runs through the narrow notch in the pipe B into the jar, the rest runs direct into the cistern through a notch in the side of the dish, the width of which is regulated by the slide S. The water in the jar dissolves the lime, and entering at the top displaces an equal quantity of this lime-water from the bottom, which overflows through the pipe E, and mixes with the fresh water entering at S.

* The water has about 17° of hardness, and 14½° of alkalinity, and requires very nearly one-twelfth part of lime-water to be added to precipitate the dissolved chalk. This is rather more lime than the London water generally requires.

How is the proportion of lime-water to be added, regulated?—By ^{Mr. Holland.} the slide at S, by which the width of the notch may be increased or diminished, so that 12 times as much water may enter the cistern



directly, as enters the jar, which of course displaces an equal quantity of the lime water it contains. In order that the flow through the two notches may continue proportionate, whatever be the rapidity with which the water enters, the width of the larger notch diminishes up-

Mr. Holland.

wards, by which compensation is made for the increasing proportionate resistance to the flow through the narrower notch, as the dish fills.*

After the liming and filtering, is the Lambeth water a first-class water?—Certainly not, far from it. It is still hard, though much less so than before, neither is it so pleasant to drink as the bright sparkling mountain water with which Manchester, for instance, is to be supplied. Nevertheless it is not much to be complained of, and I have good reason to be grateful to Dr. Clark, for showing so easy a way of improving it so much.

Can you not improve the water still more?—Yes, for washing, by adding to it a little oxalate of ammonia or of soda. I use the former. This precipitates all the lime, and makes the water very soft.

Do you consider it worth while to take all this trouble, and to incur this expense for the sake of soft water?—Certainly, it is very well worth while; in fact, without liming, I consider the water quite unfit for drinking; though it varies in quality, it has generally a very perceptible taste and smell which the lime removes. Then as to softness; I am charged 35s. a year for water (which is far too much), but, however, water costs me say 8d. a-week, but the soap for my family, in addition to that for the washing sent out, costs about 1s. 6d. a week, or twice as much as the water. It is evident that by diminishing the hardness of the water, and thereby the waste of soap, I may easily save the amount of my water-rate in that article alone. Besides that, I can wash comfortably with the softened water, but I cannot do so with any quantity of soap with the water before it is limed, unless I have it boiled to precipitate the chalk, which process is more expensive and troublesome. I should, however, much prefer being supplied with a water fit for ordinary domestic purposes, and, if necessary, paying more for it, though I think the present charge exorbitant, even if the water were good, but outrageous considering the stuff which they supply.

Is not the water for Lambeth filtered at all?—I think not, for if a flannel bag be tied round the supply-pipe, it gathers a quantity of mud resembling that on the Thames bank, and having “a very ancient and fish-like smell.”

Have you tried the difference of hard and soft water for cooking?—I have not made any accurate experiments except as to tea-making; I find that the water softened by means of oxalate of ammonia extracts the strength of tea almost twice as well as when hard. I had tea made with equal quantities of the leaf, and equal quantities of boiling water, with and without oxalate of ammonia. The infusion made with water softened by the oxalate, was stronger and better flavoured, and had to be diluted with the addition of 80 per cent. of hot water to bring it down to the strength of the other. It follows, therefore, that with the oxalate 10 parts of tea go as far as 18 without it.

Does that saving pay for the expense?—Over and over again; my tea costs me about 1s. a-week, if I can save eight parts out of 18, I can have as strong and better flavoured tea for less than 7d. a-week, being a saving nearly equal to the water-rate. It is not easy, however, to get

* Since the sketch was made, I have added a funnel to the apparatus, into which the lime-water and entering water flow, so that they may be more thoroughly mixed. I have also placed pieces of coke in the jar on which the lime rests, thus offering a large surface to the action of the water.

these savings effected regularly; it is apt to be forgotten, and cannot well be left to the servants. It would be far better to have a water originally soft, if it were procurable. Mr. Holland.

Is there any danger in using the oxalate of ammonia or soda?—Not the slightest with common care; the water does not require quite two grains of oxalic acid to the pint, to precipitate all the lime it usually contains. None of this remains in solution, and if a slight excess should accidentally be used, no harm is done, the neutral oxalates being innocent; nay even a small quantity of oxalic acid, if largely diluted, would be quite harmless.

How is the oxalate of ammonia prepared for convenient use?—By dissolving one troy ounce (480 grains) of oxalic acid in a quart of water, and adding as much carbonate of ammonia as will saturate it. Until the acid is saturated, the addition of the carbonate will be accompanied by effervescence; if somewhat more be added, it will be advantageous rather than otherwise. This quantity ought not to cost more than 3*d.* and would soften above 30 gallons of water. A small teaspoonful of the solution is enough to precipitate the lime contained in a pint of Thames water; less, indeed, will be sufficient, if part of the lime be precipitated by previous boiling. More ought not to be added if the water is to be used for making tea, as more will give a taste like that of soot.

Do you recommend this mode of softening water for washing?—It answers very well; but I think the use of caustic soda still better, if cautiously employed. Common soda, which is a carbonate, is rendered caustic if a solution of it be shaken with some quick lime, which unites with the carbonic acid, and leaves the soda free. It must be kept from the air to preserve it caustic, and used cautiously, or the clothes will be injured by it.

Do these chemical expedients enable you to avoid the evils of hard water?—To some extent they enable those who have sufficient knowledge and care to avoid those evils. It is idle, however, to expect that the population generally can employ such processes as I have described, properly; or, even if they could, that they would do so regularly. It is evidently the duty of those who have to supply a large population with water, to procure the pleasantest, softest, and purest water which is obtainable at any reasonable expense.

What amount of supply do you consider desirable in proportion to the population?—I think all calculations based upon the present consumption in any city or town in England fallacious, as I have no doubt that the consumption of water will at some future period, not far distant, be far greater than it now is.

Can you state that the present generation will ever consume at the rate of 30 gallons of water each daily?—Probably not; recent investigations appear to prove that a large portion of the supposed consumption of water, on which that estimate was based, is really waste, which may be prevented; to that amount the estimates may be diminished, but the real consumption will gradually, and probably quickly, become far greater than it now is, and there should be the means of providing for it as it arises by extension of the supply. The consumption will increase greatly, when water-closets are universal and baths very general, as I trust will, before long, be the case. There are many purposes to which

Mr. Holland. water might be usefully applied, were it provided in sufficient abundance, for which it is now little used.

You allude to opinions as to the necessity of extra supplies for flushing the sewers and cleansing the streets?—Yes; or rather to providing such a current in the sewers as would render flushing unnecessary by preventing all deposit, and in assisting in the cleansing of the streets. It often happens that streets cannot be cleansed without the aid of water; and if it be attempted, that only about one-third of the dirt is removed by mere sweeping and scraping, the rest being impacted between or adherent to the stones. This is proved by the fact, that if streets, when the mud is very adhesive, be first well watered, three times as much dirt may be removed as would be if they are swept without water, allowance being made for the water contained in the wetted mud.

If some cheaper method of watering than by the cart were devised, would not much more water be thus used?—No doubt, very much more. There is no doubt either that, even without such improvement, much more water will be used for street cleansing than has hitherto been usual, for as the public learn by experience the great advantages of water-sweeping, they will insist upon its being practised; and very wisely so, for its advantages far exceed its cost.

Have you witnessed the operation of street cleansing by jet?—Yes, in Preston, Manchester, and London, but only by way of experiment.

Do you think it will supersede sweeping?—I do not think it will; but I have no doubt that the two might be advantageously combined, to a great extent, if water were supplied abundantly and cheaply, and at sufficient pressure to afford a strong jet. It would be very useful to wash the footpaths with the jet early in the morning.

What other public uses for increased supplies of water do you anticipate?—I think it very desirable that provision should be made for numerous public fountains, not only for ornament, but to provide water for horses, cattle, dogs, and other animals. Very serious evil is now suffered by animals, especially cattle, from the absence of drinking places. I have seen, as no doubt has everybody else, bullocks driven through the streets with their tongues covered with dust, stopping at every wet place in the road, hoping to find a mouthful of water, and almost maddened with thirst. Dogs also suffer severely; and with respect to horses it is a very serious evil. It is very common for a horse to be out all day without any water, except what his driver can beg or will buy; and often the carter is so indifferent to the sufferings of the poor animal committed to his care, that he will let him pass the whole day without water at all; this could hardly happen if drinking places were as common as they ought to be.

But would not such drinking places be themselves a source of inconvenience?—I think not seriously so, if they were made small, but numerous. A horse stopping to drink could cause no more inconvenience than by stopping for any other purpose; besides, we ought to submit to greater inconvenience than is at all probable to avoid the suffering and injury inflicted. We have no right to use animals for our use or convenience without taking due care to preserve them from unnecessary suffering. It would be easy at the same places to provide means for persons to drink, which would be a great convenience to the

poor, who cannot go into a shop to ask for water. I have no doubt such a provision would check drinking of intoxicating liquors very much. Mr. Holland.

What other new demands for water do you anticipate?—They are very numerous. For instance, if water were supplied constantly at high pressure, it would be used for washing windows, and possibly the fronts of houses. If, as is probable, ornamental house-fronts be introduced, made of tiles or non-absorbent bricks, the easiest way of keeping them clean will be by jets of water. The dingy, monotonous, and gloomy appearance of our streets is a very serious evil, which it would be worth making great efforts to remove. The good effect of external beauty and cheerfulness of appearance on the manners, temper, and character of a population is very certain; but we cannot preserve architectural beauty without cleanliness; and as there is no probability of keeping the air free from smoke (though much in that way ought to be done), we cannot have cheerful, handsome streets without the means of easily cleansing the house fronts. If such means were introduced. I have no doubt that external ornament would be more freely employed; probably variety of colour would be resorted to, if the colours could be preserved from being lost in the one universal hue of soot. In the suburbs of the metropolis it is probable that many individuals would have small ornamental fountains in their gardens if they could be easily and cheaply supplied, and so increase the demand for water.

Do you anticipate still further new demands for water?—Yes, many. For instance, at present many tradesmen employ very small steam-engines for purposes that may be almost as cheaply accomplished by hand, for instance, coffee grinding. There are many purposes for which steam might be substituted for manual power with advantage were it not for the cost of the skilled labour required to attend to it, and the expense and trouble of keeping up the steam when the power is not wanted. If some hydraulic engine, such as the *tourbine*, were employed, and worked by water from the pipes, which could be set at work and stopped in an instant, consuming no power except when at work, requiring no skilful mechanic to work it, and being quite free from risk from fire or explosion, there is no doubt that numerous applications of such power would be introduced which are, as yet, scarcely thought of. It would be easy to work cranes and hoists for raising and lowering goods and persons in warehouses, where the occasions for their use are not sufficiently numerous to make a steam-engine economical. Such an instrument would work presses in the smaller printing-offices where it is not worth while having a steam-engine. For many purposes a simple hydraulic press with a large cylinder acted upon by the direct pressure from the pipes would be sufficient for packing. In others, *Bramah* presses might be worked by the hydraulic engine. Turners might work their lathes, and smiths their bellows by water-power; chaff might be cut, and oats and beans crushed by the same means; in fact, it is impossible to mention all the various uses to which it might be applied, if water were supplied constantly and at high pressure. The little engines now used are sometimes procured rather to attract attention to their owner's shops, than for any economical employment of the power; the same end would be attained by engines worked by water pressure. I have no doubt that an extensive new trade will gradually grow out of the application of

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water-power to small purposes, when the system of constant service at high pressure shall be in operation in London, Manchester, and Liverpool, and the other great seats of industry. In order, however, that this may be the case, the supply must be ample and the charges to large consumers very moderate. I may mention that water-cranes are now in use at Liverpool and Newcastle, and are, I understand, economical even at the present charges of the Companies for water.

But with such charges could a fair income be derived by supplying water for these mechanical purposes?—No doubt of it. I have known a warehouseman pay 20*l.* a-year rent for the occasional power derived from a neighbour's steam-engine, for working his packing-presses. Many persons now employ little steam-engines which are uncertain, troublesome, and dangerous; if the same power were given by water without the trouble, uncertainty, and danger, many more persons could employ it than now use steam-engines, and the cost might be far less than that of the engines, and yet leave a handsome profit on the cost of procuring the extra quantity of water required.

What is the source of such economy? Does it not require as much extra power to lift the water required to work these hydraulic engines as they can possibly exert?—Certainly, more by the friction lost. But large engines are employed for pumping and small ones are got rid of, and the cost of a small engine is very great in proportion to the power it exerts, especially if it be not worked constantly; the cost of attendance, repairs, &c. being very great in proportion to the power. With simple hydraulic engines, on the contrary, no special attendance would be required, and there need be no expense incurred, except when the engine was actually at work. The suppliers of the water and the employers of the power would divide the resulting advantages, the former might sell this power (for small purposes and for only occasional uses) for much more than it costs, and yet supply the customer with power for such purposes cheaper than he could obtain it in any other way.

And you think there would be a large demand for water for such purposes?—No doubt of it. At a very small cost any persons wishing for the services of a one or two horse engine for an hour or two a-day, might have it without trouble, risk, or uncertainty; and there is no doubt that such an advantage would be very extensively used. Though the introduction of such novelties would, of course, be gradual, I do not think it would be very slow, if the charge for the power were not very much more than the cost of raising the additional water required and the expenses attending its distribution.

Have you known very serious domestic mischiefs produced by the insufficient supply of water?—I am not acquainted with the domestic life of the London population; but in Manchester the evils I have become acquainted with from want of water are of enormous magnitude. In that town a very large proportion of the population (in 1847 nearly one half) have their supply of water from pumps, the great majority of these get it from pumps which are kept locked up, except during a short time each day, consequently the supply procurable is very scanty. This scantiness of supply leads to great neglect of cleanliness; for instance, I have known the water used for washing a room kept to wash it with again and again, till it became dreadfully offensive. I have known persons come to their work unwashed, and

wash themselves at their employers, because they had no water at home. I have known a man wash himself in water so offensive that it made his eyes sore, and I have frequently known the only water to be got to drink evidently and perceptibly polluted from some neighbouring drain or cesspool. It is impossible to doubt that such circumstances must debase a population and must render them prone to resort to beverage less disgusting. It is in short impossible to overestimate the importance of securing to the *whole* population an ample supply of pure water. A good water supply, ample in quantity, and universal in distribution, is an essential preliminary to sanitary improvement.

It is understood that you have given much consideration to the machinery by which sanitary improvements should be worked. Do you agree in the opinion that the control of the water supply and of the drainage should be vested in the same authority?—Decidedly, and for various reasons. In the first place not only are both proper water supply and proper drainage necessary for every inhabitant, but each is essential to the other; without proper water supply the drains are certain to become the receptacles of decomposing filth, and themselves sources of disease and danger, and without drainage, water supplied is apt to become a nuisance by causing dampness. Secondly, the works for bringing pure water into and carrying foul water out of the houses are more economically, and likely to be more effectually, constructed together than separately. Thirdly, though it is essential that water enough to carry away the filth be supplied, waste is injurious, not only because it requires more power to pump it in, but because much of it will have to be pumped out again if the lower sewers are to be kept clear at all times, and still more so when the sewage is used for agricultural reproduction. Those who will be most inconvenienced by the waste (*i. e.* those who will have to dispose of the sewage) ought to have authority over the supply, for which reasons, among others, the water supply and the drainage ought to be placed under the same authority.

Is it not also desirable that the paving and cleansing of the streets should be placed under the same authority as the water supply and drainage?—Such a consolidation of authority would be a source of greatly increased economy and efficiency. No one ought to be allowed to meddle with the streets except those appointed by the authority responsible for their proper condition. If, as sometimes happens, one authority direct the formation of the streets, another their repairs, a third their cleansing, a fourth their drainage, while a fifth and sixth are empowered to tear up the pavement for laying down and repairing water or gas-pipes, the public can have no security for such streets ever being in good condition. It is true that such extreme division of authority is not common, but it is possible, and to a greater or less extent, such injurious division of authority is universal. Where authority is divided responsibility is to a great extent destroyed.

Would there be any further public advantage from having all these matters under one and the same control, besides that of increasing the responsibility?—Yes, very great. If streets be properly made and kept in proper repair, less detritus is carried into the sewers, and less trouble and expense is incurred for keeping them clear; and if those who

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have the control of the streets have also the control of the water and sewers, they may greatly facilitate and economise the proper cleansing of the streets on which their maintenance in good condition so much depends. Water might be economically used for cleansing to a very great extent, either with the jet or water-cart, if it were supplied at cost price, and if it were not for the cost of carting it away in the form of slop. This cost might be avoided by making arrangements by which the slop (produced by wetting the streets previous to sweeping) might be conveyed away through the sewers. There would be no danger of obstructing the sewers by shooting the slop into those only of large run, and the manure need not be lost, as the sweepings would add to the strength of the sewage. Of course the public would receive the advantage of any economy thus produced, either in increased comfort or diminished expenses, and many lay-stalls might be got rid of, and the nuisance of slop-carts in the streets avoided.

Are you aware of any serious inconveniences and disadvantages from the large number of different authorities having control over the various streets of the metropolis?—The disadvantages are very great. In many instances there is a very disproportionate expence incurred for superintendence; in others the officers are paid for part only of their time, and often are not paid such salaries as will secure men of sufficient education and knowledge. If the districts were larger it would be *evidently* worth while to secure for officers men of higher rank, who would devote themselves exclusively to their duties. Again, the great subdivision of London leads to great injustice. Suppose the inhabitants of one parish are desirous of having their streets in good order and clean, unless the adjoining districts concur a great and unjust expence is imposed upon the cleaner parish, because every vehicle which passes from a dirty on to a clean street carries dirt from the former to the latter, and renders cleanliness more difficult and expensive. Further, the inhabitants of London have an interest in the condition of other streets besides those of their own parish. Besides the inhabitants of Regent-street, for instance, all the riders in the 5,000 vehicles that daily pass through that great thoroughfare are affected by its condition, and the inhabitants of Regent-street, who have to bear the cost of keeping that street in good repair and well cleansed, *for others benefit as well as for their own*, may fairly feel aggrieved if they do not experience the benefits of good and clean streets when they go into other districts. It is evident that justice to all requires that in every part of London the streets should be kept in equally good condition, and as the indirect losses occasioned by their being badly paved or badly cleansed far exceeds the cost of keeping them in a proper state, it is to the interest of all that all streets should be well kept. This, however, never will be the case so long as there are the multitude of petty and uncontrolled authorities that now exist. Either one authority should be appointed, responsible for the condition of the whole metropolis, representing and acting for the whole, or the various local authorities should exercise their powers subject to the superintendence and control of a central authority. I have no hope that the present evils will be got rid of, without changing the system of local government (practically irresponsible) under which they have grown.

Dr. Arthur Hassall examined.

1. You are a graduate in medicine of the London University?—I am a Bachelor of Medicine of the London University, and a Fellow of the Linnæan Society.

2. Have you directed much attention to subjects of natural history?—I have; to various branches of zoology and botany.

3. Have you directed your attention both to vegetation and to the animal life which accompanies vegetation in waters?—I have, and especially to the vegetation occurring in fresh water, upon which, in 1842, I published a distinct work, entitled “A History of the British Fresh-water Algæ,” and which contains figures and descriptions of nearly 500 species.

4. In the course of your investigations have you examined many river waters?—I have examined the waters of the Thames, the Ravensbourne, the Lea, and the New River, also those of the rivers Colne and Wandle and the springs connected with these.

5. At what points have you examined the Thames water?—I have made a series of observations at various points between Kew Bridge upwards, and Woolwich downwards. I have also examined it at Brentford, Richmond, and at Henley-on-Thames.

6. At what points have you examined the New River?—I have examined the water of the New River at the Spring heads near Ware, at the reservoir at Cheshunt, and also as supplied to the public; obtaining it from the service-pipes of different cisterns.

7. At what points have you examined the Colne?—As the river passes through the town of Watford, and at the spring situated in the neighbourhood of the town.

8. At what points have you examined the Wandle?—At the large pond which receives the drainage of the town of Croydon, at the springs at Waddon, and also at Beddington, below Croydon.

9. What waters have you examined which may be called pure waters, to serve as a standard of comparison?—The waters of the deeper wells, and spring-water in general, these containing little or no living organic matter.

10. Have you examined any waters off the granite, or any surface-water?—I have not yet had an opportunity of examining any water off granite: I presume that the greater portion of the water of rivers is to be regarded as surface-water.

11. Have you examined rain water?—I have made several examinations of rain-water immediately after its descent to the earth, obtained in both town and country, and can confidently assert that it does not, in general, contain any form of living animal or vegetable matter: in procuring rain-water for microscopic examination, it is necessary, however, that certain precautions should be adopted in its collection; thus, the vessel into which it is to be received should be placed far away from houses or other buildings, and also raised some two feet above the surface of the earth; or otherwise, in some cases, the drops of rain will bring down from the roofs and sides of the houses sporules and filaments of *conferveæ*, the ova of *infusoria*, &c., the former of which are frequently very abundant on damp walls, sheds, palings, trees, &c.

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12. Have you made any examination of the water of rain-butts?—I have examined the water of two butts, and that of one of them at two distinct periods; the first examination was made a week after its fall, in this I could not detect any trace of organic matter dead or living, while the second examination was made at the expiration of a fortnight; on this occasion I observed two or three extremely minute *infusoria*, probably *monads*, and globular bodies, possibly ova; the water of the second butt was also examined at the end of a fortnight, and its condition was as nearly as possible the same as that of the water of the first butt at the corresponding time.

Previous to the recent rains both butts were empty, otherwise the extent and variety of the living organisms presented would, no doubt, have been greater, as these wooden butts and vatts serve to harbour and greatly encourage, exposed as they usually are to light and air, the development of the lower forms of animal and vegetable life. I would now observe that every moving particle noticed in water must not be mistaken for a living production, as inorganic substances reduced to a certain state of division display active movements.

13. You would regard, then, rain-water as one of the purer waters?—Yes; as the purest of all water, except distilled water; and I would observe that the quantity of organic matter contained in the water of the two butts submitted to examination bore no comparison to that present in river water, being at least a hundred-fold less.

14. You are probably aware that it has been stated that waters caught out at sea in sails and casks have an appearance of visible *animalculæ*?—If the rain-water contained in the cask were in any degree exposed to the influences of light and air, it is very probable that, after a certain time, *infusoria* would become developed in it.

15. It has been stated that *animalculæ* are to be found in rain-water, however quickly it may be caught after its fall?—I should doubt the accuracy of the statement, it is opposed to my own observations; and it, moreover, appears to me that most *animalculæ* would not meet with in water, in a state of vapour or rain, the conditions necessary for their existence. Rain-water, just fallen, might indeed be readily conceived to contain in some cases the sporules of fungi, and the ova of *infusoria*.

16. But do not some rains bring down with them *animalculæ*?—In some cases, in different parts of the world, living productions, both animal and vegetable, have descended in showers of rain, but such occurrences are rare and exceptional.

17. Are you aware what difference it makes, as regards vegetable growth, whether the water is hard or soft?—I should not consider that that circumstance would occasion much difference in the amount of vegetation contained in water, this being more influenced by air, light, and rest.

18. As a general rule, does not this phenomenon occur if you expose water to air and light, *algæ* form rapidly?—Yes, the development of vegetable and animal life is essentially connected with free exposure to the influences of air and light.

19. The more rapid forms of vegetation occur repeatedly, decay, and then animal life appears?—Yes; such is the usual order of succession.

20. Have you made any experiments for the purpose of determining accurately the effects on the development of vegetable and animal life, of the exposure of water to air and light, and also the effects of the deprivation of these agents?—Conceiving the determination of the effects of air and light on the development of the lower forms of vegetable and animal life to involve points of much practical importance in reference to the conveyance of water long distances, and to the system of reservoirs and cisterns, I have instituted, with the above view, several experiments, the more important of which I will proceed to relate in as brief a manner as possible, commencing with those which have reference to the *combined influences of air and light*.

Into a number of bottles filled with water, there were introduced living animal and vegetable productions appertaining to each of the principal classes of the lower forms of organic life, as follow: 1. *Entomostraceæ*; 2. *Infusoria*, the Thames *Paramecium*, and *Oxytrica* principally; 3. Green *Infusoria* of the genus *Euglena*; 4. Filaments and sporules of green *Conferveæ*; 5. *Desmideæ*; 6. *Diatomaceæ*; 7. *Fungi*.

Examined at the expiration of a week, the several organisms, animal and vegetable, were found to be in a living state.

Again examined, at the end of five weeks, the various productions, with the exception of the Thames *paramecium*, were found not only to be in a living condition, but to have multiplied greatly, other species having made their appearance; this increase was particularly evident in reference to several species of *diatomaceæ* and the green sporules of *conferveæ*, these having increased to such an extent as to cause the water to assume the green hue of pond-water.

The Thames *paramecium* had disappeared, but the *oxytricæ* were abundant.

In the next experiments the *air was excluded*.

The same number of bottles were filled in the same manner as in the first experiments, but in place of being open to the air, they were corked and sealed. Submitted to examination at the end of the first week, the several productions were observed to be living, and the *entomostraceæ* and *infusoria* to be as active in their movements as ever.

Examined a second time, at the expiration of the fifth week, except in the case of the Thames *paramecium*, there was an evident augmentation in the number of living productions, this being most evident in respect to the *entomostraceæ*, *conferveæ*, and *desmideæ*, of the genera *scenedesmus* and *closterium*; the increase, nevertheless, was obviously not so great as in the previous experiments, where the productions were exposed to both air and light.

In the following experiments the *light was excluded*, but not the air.

The same number of bottles were prepared as in the previous cases.

At the termination of the first week the several forms of animal and vegetable life were observed to be still in a healthy condition, the only change observable was in the green *infusoria* and *algæ*, which appeared of a paler colour than at first.

At the end of the fifth week the following changes had occurred: the *entomostraceæ* were dead, and the Thames *paramecium* could not be detected, but in the same bottle of Thames water there were present, in a living state, *annelidæ*, *oxytricæ*, *rotifera*, and a large blue *stentor*;

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the two last were not visible in the water when first placed in the bottle; the green *euglena*, *conferveæ*, and *desmideæ* were bleached and dead: no certain conclusions could be come to with respect to the *diatomaceæ* and *fungi*.

In the last experiments both *light and air were excluded*.

The results were nearly similar, but still more marked than in the former experiments; in the bottle filled with Thames water but a single *paramecium* was to be seen, but two or three *annelidæ* and several *oxytriceæ*, and *rotifera*: the *rotifer* appeared to be of a different species to that present in the same water not excluded from the air, and there were in the last no examples of the blue *stentor*.

In no cases in which light was excluded could an actual increase in the number of living productions be ascertained, except in reference to the species of *infusoria* of the genera *stentor* and *rotifer*.

Although no special experiments were made with the *annelidæ*, yet the occurrence of these at the expiration of five weeks, in Thames water excluded from both light and air, shows with what tenacity the vital principle is retained in them.

From the preceding experiments the following conclusions may be deduced.

1st. That the combined influences of light and air favour, in a high degree, the growth and development of the lower forms of animal and vegetable life.

2nd. That for the limited growth and development of the majority of these forms, a partial exposure to air is sufficient, since many species increase and multiply in sealed vessels.

3rd. That light is decidedly necessary to the prolonged existence of the *entomostracæ*.

4th. That it is not less necessary to the green *infusoria* and *algæ*.

5th. That while many species of *infusoria* live for a long time deprived of light, there are other species, the development of which would appear to be favored by its abstraction.

21. Does not temperature effect the development of the more simple forms of vegetable and animal life?—Yes, very much so; common observation is alone sufficient to show the powerful operation of temperature upon the organic world; the chill and lifeless aspect of nature in winter, contrasted with the redundance of life in summer, air and water teeming with thousands of strange and harmonious forms of existence, must be apparent to the most superficial observer, however the various divisions of the organic world, even the lower forms, do not run an equal or precisely similar course.

Thus the green *algæ*, the *conferveæ* especially, are amongst the first productions to feel the influence of temperature, and many species on the approach of warm and genial weather start into life and activity with wonderful celerity, and again on the approach of the cold of autumn and winter as quickly die, and disappear for the most part.

The *desmideæ* and *diatomaceæ* are more hardy than the *conferveæ*, especially the *diatomaceæ*, and these may be found in great numbers all the year round, but still their proper season is the summer.

The *fungi* are one class of nature's scavengers, and their proper season is the autumn, that is, they are most abundant just when their

services are most needed, viz., when dead and decomposing vegetable and animal substances most abound.

The green *infusoria*, as the several species of the genera *euglena*, *microglena*, and *cryptoglana*, &c., would appear to be equally susceptible of temperature with the *conferveæ*, and are most abundant in the spring.

While the *entomostraceæ* and *infusoria* in general are most abundant in the spring and summer, yet many species live in great numbers through the winter, this is the case with the Thames *paramecium*.

The *annelidæ* are very hardy, and are to be found abundantly in winter.

22. Have you tried the effect of boiling upon the *infusoria* and *algæ*?—I believe that the vitality of every kind of living production found in water in general is destroyed by the temperature of boiling water, the only question is in respect to the *fungi*; this is a matter, however, that might be readily put to the test of positive experiment. That the vital principle is destroyed in the great majority of instances by boiling is shown by the following experiment. Two bottles of boiled Thames water were put aside, and examined at the end of a week, the one having been exposed to the air, and the other corked, the only living production contained in either was a minute species of *infusoria*, probably a monad; and this was more abundant in the water exposed to the air than in that excluded from it. A second examination, made at the end of the fifth week, did not disclose the presence of any other organism.

In certain natural and boiling springs, living productions, animal and vegetable, have been noticed, but these are of different kinds to any of those met with in the waters usually employed for domestic purposes.

The skeletons of the *diatomaceæ*, being of flint, are not injured by boiling, and retain their forms, even in boiling nitric acid.

23. Is not the development of the lower forms of vegetable and animal life very much favoured, not merely by exposure to air, light, and temperature, but also by a motionless and stagnant condition of the water?—Yes; very much so; the abundance as well as the forms of vegetable and animal life which occur in water depend greatly upon its condition as to rest or motion: thus life is much more abundant in still than in running water, and the forms are different in the two cases; in old ponds, on heaths, amongst vegetation, we meet with the *desmideæ* principally, as well as numerous *infusoria*; in ponds, in fields and parks, not of such great extent as to deserve the name of lakes, we notice chiefly *conferveæ*, as well as certain *infusoria* and *entomostraceæ*; in lakes and ornamental waters but few *conferveæ* are present, but numerous *diatomaceæ*, *infusoria* of the genera *aneurea*, *brachionus*, *peridinium*, also *entomostraceæ* abundantly; the water of slowly running streams has no very distinctive character, but contains *diatomaceæ*, *conferveæ*, *infusoria*, and *entomostraceæ*, in nearly equal proportions, while that of the more rapid streams and rivers is remarkable for its comparative freedom from minute organisms, vegetable or animal, and those which do occur are of different species; thus amongst the *conferveæ* the principal species met with are *gladophora*, *glomerata*, and *lyngbia zonata*, both of which have roots.

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24. What is the depth at which aquatic vegetation will grow?—In the clear and transparent water of the sea vegetation will grow at a considerable depth, but still not beyond the influences of air and light, while in fresh water but few species are to be found growing more than a very few feet below the surface; this is in part due to its comparatively less transparency, and in part to other causes. Almost all the marine *algæ* are furnished with roots, by means of which they attach themselves to the rocks, while but few of the fresh water species are provided with any such organs; one of the reasons of this difference is obvious, the constant motion and agitation of the waters of the sea necessitate the provision of roots, which in still, fresh waters would be entirely useless. The second reason is less apparent; the function of respiration is one of the greatest importance in all plants, including the *algæ*; in the sea these are brought within the direct influence of the air at each period of the recession of the tide, and hence their attachment to rocks at a considerable depth below its surface does not interfere materially with the process of respiration or aeration; in still waters in general there is no tide, and the *conferveæ* rooted at the bottom of a pond or river would be removed constantly, and to a great extent, from the action of air, light, and heat, and this is the second reason why the fresh water *conferveæ* have no roots; they float, therefore, freely in the waters in which they dwell, now at the bottom, now on the surface, according to varying atmospheric conditions, thus when it is light and the sun shines the process of respiration is in full activity, oxygen is evolved; this collects in bubbles, which become entangled amongst the filaments of the *conferveæ*, causing them at length to become lighter than the water itself, and so occasioning their ascent to the surface, where they remain until night approaches, or a marked change in the weather comes on, when the gaseous bubbles having escaped into the air, and no renewed formation of them occurring, they become once more heavier than the water and again subside.

25. What would be the least depth, according to your observation or information, at which water ought to be stored in open reservoirs, *i. e.*, in reservoirs of too large a capacity to be roofed?—I should say not at a less depth than from 10 to 15 feet, and the deeper the better, the greater the depth of the water the less surface in proportion would be exposed to air, light, and heat, the circumstances favouring development. A large surface of water can scarcely be exposed freely to the above influences without its purity being more or less injured, nevertheless the abundance of vegetable and animal life in an open reservoir does not solely depend upon exposure, but is also closely connected with the condition of the water by which the reservoir is supplied. If it be not contaminated with sewage, and do not contain the sporules and ova of *algæ* and *infusoria*, I have but little doubt that water might be retained for a short time in an open reservoir in a pure and wholesome condition, almost, if not quite free from living organic matter.

26. What should be the speed per hour of water in shallow channels to prevent such growths?—Not less than from three-and-a-half to four miles an hour. I do not consider, however, that this speed would entirely prevent the development of the lower forms of vegetable and

animal life, but it would, no doubt, be sufficient, greatly to lessen their numbers and to modify the varieties.

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27. What length of time, in your opinion, may water be retained in an open reservoir without any material alteration of its purity?—That will depend very much upon the character of the water supplied to the reservoir, and on the management and state of the reservoir itself; if the water be of an impure kind, and contain either dead or living organic matter, or both, as in the case of Thames water, then it could be kept in the reservoir but a few hours without suffering a further deterioration, and the period would be still shorter if the condition of the reservoir was itself bad, and if the organic matter derived from the water were allowed to go on accumulating from day to day, week to week, and even year to year, as it is frequently allowed to do; where such is the case, there is at all times an enormous amount of putrescent organic matter present, capable in a very short time of seriously contaminating the water by the effects of its decomposition, and entirely independent of the pabulum which it affords for the sustenance of myriads of *infusoria*; but if on the other hand the water poured into the reservoir was of any of the purer kinds, as rain, spring, well, or even the purer river waters, previously filtered, and due attention were at the same time paid to the state of the reservoir, then I believe that any of these waters might be retained in it for many weeks without prejudice to its purity.

28. Have you made any experiments in order to elucidate the question of the stowage of water?—The effects already detailed of the exposure of water to the influences of air, light, and temperature are intimately connected with the stowage and conveyance of water, nevertheless, I propose to try the following experiments, and to place on the top of a high house six vessels, each capable of holding two gallons of water, the one to be filled with distilled water, a second with rain water, a third with water from a deep well, a fourth with well water and dead animal matter, a fifth with the same and vegetable matter, and the sixth with the same kind of water and a mixture of both vegetable and animal substances: the results of these experiments require time for their development, but their probable nature it is not difficult in some respects to anticipate.

29. Have you observed the Serpentine, or other ornamental waters, or canals, so as to be able to state, from observation of the vegetation, the condition of animal life contained in them?—I have examined the water of the Serpentine, of the large pond opposite Kensington Palace, and of the ornamental water in St. James's Park.

30. What was the condition of the water of the Serpentine?—I observed in it a considerable number of *diatomaceæ*, principally of the genera *surirella*, *exilaria*, and *navicula*; of *infusoria* of the genera *aneurea*, *brachionus*, *peridinium*, *euglena*, *rotifera*, and *polyarthra*; of *entomostraceæ* of the genera *lynceus* and *cyclops*; of *zoophytes* of the genera *hydra* and *alecyonidium*.

The condition of the water was worst at the Bayswater end, where the *diatomaceæ*, *oscillatoreæ*, and *rotifera* were principally found, while at the Hyde Park extremity the water was clear and bright, depositing but little sediment, but yet in each drop examined with

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the microscope numerous *infusoria* were in general to be detected.

The first microscopic examination of the water of the Serpentine was made early in the spring, and while the weather was still very cold, the particulars given above refer to its condition at that time; since that period, however, matters have changed much for the worse in consequence of the increased temperature, and the amount of animal and vegetable life now present is many times greater, in particular the green matter which attracted so much attention a year or two since has again made its appearance in vast abundance. In reference to this matter I beg to introduce the following particulars, extracted, in part, from a communication which I have just prepared for the "London Botanical Society" on the colouration of the water of the Serpentine.

The sudden and periodical colouration of large bodies of water is one calculated to excite considerable interest, from the extent of the phenomenon, as well as from the mystery in which, to the common observer, it is generally involved.

The interest usually attending this phenomenon from the circumstances above referred to is enhanced in the present instance by certain important sanitary bearings.

The colouration of the water of the Serpentine is no new phenomenon, since it has been observed now for several years, and in fact has become annual.

Although many persons have expressed the opinion that this colouration is occasioned by a vegetable production, I am not aware that any observer has yet accurately determined its nature, or has given any description of the species which produce it. Dr. Tilt has even given a figure of a *confervæ* to the presence of which he considered that the colouration was due; the species represented by Dr. Tilt, is, however, very different from that which really occasions the phenomenon.

The production which undoubtedly causes the colouration belongs to the class *algæ*, is one of the family *Nostochineæ*, is the *Anabaina Flos. aquæ* of Harvey and myself, the *Dolichospermum Thompsoni* of Mr. Rolfs, and the *Coniophytum Thompsoni* of this communication.

Into the technical or scientific description of this production it is not necessary here to enter, it will be sufficient to notice the general facts connected with its presence in the Serpentine.

A month since, on walking round the Serpentine, I did not see a trace of this *algæ*; a week previous to first noticing it, which was on the 16th of June, I have been assured that not a vestige of it could be discovered. On the date referred to, the whole of the north bank of the Serpentine, from the bridge eastwards, was coloured of a deep ceruginous or coppery green, the depth of colour increasing as the eastern extremity was approached. According to the evidence of one of the boatmen this extensive colouration took place in the course of one warm and sunny day.

On the occasion of a second visit made the following day, the distribution of the plant was much the same, only that it appeared to have increased greatly in quantity, and there was a vast accumulation of it at the eastern extremity, where the water was coloured as far as the eye could reach, the colouration extending to almost to the opposite side.

Now this was not mere surface colour; a thickish pellicle of a vivid green, broken and variously streaked, floated indeed upon the surface, but the water beneath this was also deeply coloured, so that a bottle filled with it appeared of a bright metallic green hue; dogs, as they swam in the water, splashed up a green liquid; bathers, as they emerged from it, came up covered with this *confervæ*: the effect on the smaller fish, principally gudgeon, was remarkable; the plant, from its abundance and minuteness seemed to blind them, and the water where the algæ most abounded was kept in a constant agitation by their struggles, so that blinded as they were, numbers of them fell an easy prey to the eager children who were on the watch for them.

In order to form as correct an idea as possible of the quantity of this plant present in the water of the Serpentine, I took a boat from the boat-house situated near the centre of the north bank, and was rowed out into the middle of the river; a basin full of the water obtained there, presented a decided green hue; as the opposite bank was approached the colour entirely disappeared, so that in walking along this side of the Serpentine not a trace of the plant was to be seen.

The sudden appearance of this algæ is a remarkable fact in its history; another curious fact is its occasional equally sudden disappearance.

In what way are these phenomena to be explained? Is the sudden appearance of the plant in the first instance due to its exceedingly rapid development and growth, and its disappearance to its decay and dissolution? I think not; the gemination commences, I believe, beneath the surface of the water, and early in the spring; its diffusion through the water, and its ascent to the surface taking place at a later period, and being determined by temperature: on the first approach of warmth the plant rises and forms the green scum or pellicle already described, the quantity of which increases with the heightened temperature of summer: the immediate cause of the ascent is the respiration of the plant, and the disengagement of gaseous bubbles which render it specifically lighter than the water.

The disappearance of the algæ, which is sometimes surprisingly complete, is observed to occur in rainy, cold, and rough weather, and is due to its descent in the water occasioned by increased specific gravity, the result of impeded respiration, and the consequent absence of any disengagement of gas.

As already noticed, the *Coniophytum Thompsoni* is not equally diffused throughout the water of the Serpentine, but is limited to certain parts of it, and these are subject to much variation; this partial and variable distribution is dependent upon the sun, the direction of the wind, and the flow of the water towards the eastern extremity, which accounts for its very general collection in such quantity at that situation.

This variation, in some cases, is remarkable. On the 22nd instant, I walked all round the Hyde Park division of the Serpentine, and was astonished to find that the plant had apparently vanished, and that although so abundant scarcely a week since, not a trace of it was now to be seen, the weather at the same time being warm and sunny; in this case there were but two ways in which its disappearance could be accounted for apparently, the wind at the time being north-east, might

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have driven the confervæ through the arches of the bridge into the Kensington half of the Serpentine, or else at high water-mark it might have drifted over the water-fall, below which I observed a great accumulation of confervæ, &c.

The appearance and disappearance of the plant in question is especially deserving of notice, because it shows that in order to form a correct opinion as to the condition of the water of the Serpentine, it is necessary to examine it repeatedly; a want of knowledge of this fact might lead the observer into error, and he might conclude from not seeing it on the occasion of his first visit that the accounts given of its state were much exaggerated. These few observations complete the general description of the plant, and of the phenomena connected with its presence in the Serpentine; we have now to consider it in a sanitary point of view.

It may be safely assumed, I think, as a general rule, that the green or confervæd algæ when introduced into the system speedily perish without producing any ill effects upon the animal economy; this view is based upon the organization and requirements of this class of vegetable productions; there is, therefore, no reason to suppose that the species under consideration, if introduced by any accident, as in bathing, into the stomach, would be productive of directly injurious consequences.

The presence of this confervæ in such immense quantities in the water of the Serpentine has, however, certain indirect bearings upon health; thus many persons are deterred from bathing in the Serpentine, and it is very probable that those who are not so deterred do, in some cases, suffer injury; thus those who bathe in this green water emerge from it covered from head to foot with this plant; now, as it is not easy to remove it entirely from the skin, it is quite possible that in the efforts to do so some of the slender threads and minute cells become impacted in the cutaneous pores to the impairment of the functions of the skin.

There is, however, another view to be taken of the occurrence in such great abundance of this production more important than the preceding, viz., that where not hurtful itself, it is yet to be regarded as a test of impurity, and as an indication that the waters of the Serpentine are not at present in a wholesome or healthful condition.

The phenomenon of the colouration of large pieces of water by means of confervæ is by no means uncommon; several instances of such coloration have now been recorded, and the species to which the attention of this Society has been this evening directed, has once before been observed by Mr. Thompson, of Belfast, "floating like powdered verdigris on one of the small Lacks Maben, Dumfriesshire." The most remarkable instance of the colouration of water from this cause hitherto recorded is that of the Red Sea, which, as is now well known, owes its colour and name to the presence of a minute and blood-red algæ.

I will conclude this communication by addressing a caution to the observer that he must not in all cases when he sees fresh water coloured of a vivid green conclude that the cause is some species of algæ, for the phenomenon is very frequently, and I believe most frequently, due to myriads of infusoria of the genera *Microglæna*, *Cryptoglæna*, and *Englæna*.

31. What was the condition of the pond near Kensington Palace?—

Nearly the same forms of vegetable and animal life occurred in it as in the Serpentine, but altogether in greater numbers; the peculiarity of this water consisted in the presence of the Thames *paramecium*, which is explained, I believe, by the fact that the pond is supplied in part with Thames water, furnished by the Chelsea Company.

32. What was the state of the ornamental water in St. James's Park?—It contained but few *diatomaceæ*, nearly the same forms of *infusoria* and *entomostraceæ* as the Serpentine, although in somewhat lessened numbers.

I would now observe that the condition of the several waters, the results of the examination of which are given above, closely resembles that of the waters of the numerous ponds belonging to or connected with the Hampstead Water Company, from which it appears probable that the state of other pieces of water of a similar origin and nature would not be found to be dissimilar.

33. As sources of supply to which would you give the preference, small or large rivers?—To large; the water of small rivers is for the most part drainage-water; it is easily contaminated, a single mill, or other source of impurity, being sufficient to affect the stream for its whole course; and, lastly, it contains the washings out of innumerable ditches, and which generally contain *diatomaceæ*, *conferveæ*, and *infusoria* in the greatest abundance. The water of large rivers is to be preferred for the following reason:—The greater part of the water contained in the bed of a river of any magnitude must have proceeded from considerable distances; now, water as it flows along purifies itself, the living productions contained in the nearly stagnant water of ditches, and which is apt enough for their development, transferred to the bed of a flowing river, become for the most part broken up, dead, and destroyed, deposited at the bottom of the river or dissipated by decomposition.

34. Do you find great varieties of vegetable and animal life in water?—I do; the number of distinct species which occur amounting to several hundreds.

35. What purpose do you suppose the *algæ* to perform in fresh water?—That of purifying and oxygenating the waters in which they are found.

36. Will you state, in popular terms, what you have found the variations in vegetable and animal life to be in different waters?—The purest description of water I have yet examined is rain water and that of the deeper wells and springs in general, in which I have found very little vegetable or animal matter in a living state. In the water of the shallower wells, in that of the Thames high up, and in the smaller rivers, which are not under the influence of the drainage of large towns, I have found both vegetable and animal productions, the former, however, predominating. But in the Thames, from Kew Bridge to Woolwich, animal life predominates amazingly. In other water exposed to similar deteriorating influences I have found the same forms of infusoria as in the Thames within the limits above referred to.

37. It is stated by Ehrenberg, as a general law, that where there is animal life in water visible to the naked eye, there is always a chain of animal life beneath it down to invisible existence. Have you found

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38. What species of infusoria represent the highest degree of impurity in water?—The several species of the genera *Oxytricha* and *Paramecium*.

39. What species is most abundant in the Thames from Kew Bridge to Woolwich?—The *Paramecium Chrysalis* of Ehrenberg; this occurs in all seasons of the year, and in all conditions of the river in vast and incalculable numbers; so much so that a quart bottle of Thames water obtained in any condition of the tide is sure to be found on examination with the microscope, to contain these creatures in great quantity.

40. Do you find that the infusorium of which you have spoken varies in number in the different parts of the river between Kew Bridge and Woolwich?—I find that it is most abundant in the neighbourhood of the bridges.

41. Then the order of impurity of Thames water, in your view, would be the order in which it approaches the centre of London?—Yes.

42. You find then, in Thames water, about the bridges, things decidedly connected with the sewer water, as vegetable and animal matter in a state of decomposition?—I do; about the bridges, and in the neighbourhood of London there is very little living vegetable matter on which animalculæ could live; the only source of supply which they have is the organic matter contained in sewer water, and which is to be regarded as the food of these creatures. Where infusoria abound, under circumstances not connected with sewage, vegetable matter in a living condition is certain to be met with. A knowledge of what constitutes the food of the infusoria has practical bearings upon the purity of water of no inconsiderable importance.

43. Then you regard the abundance of these creatures in Thames water as a clear indication of the presence of vegetable or animal matter in a state of decomposition?—I do.

44. May not their number then be taken as one test of the presence of noxious matter in the water?—Yes, certainly; and I should consider the test as a most unerring one.

45. What office would you attribute to the animalcules contained in impure waters, and especially in that of the Thames?—That of removing in the least injurious manner the organic matter contained in those waters. The infusoria are to be regarded in fact as one class of nature's scavengers.

46. Have you made any examination of the sewer-water with which the Thames is so largely impregnated?—I have examined the sewer-water of several of the principal sewers of London.

47. Will you state the results of your examination?—I found in sewer-water, amongst many other things, much decomposing vegetable

matter, portions of the husks and the hairs of the down of wheat, the cells of the potato, cabbage, and other vegetables, while I detected but few forms of animal life, those encountered, for the most part being a kind of worm or anælid, and a certain species of animalcule of the genus monas.

48. How do you account for the comparative absence of animal life in the water of most sewers?—It is doubtless to be attributed, in a great measure, to the large quantity of sulphuretted hydrogen contained in sewer-water, and which is continually being evolved by the decomposing substances included in it.

49. Have you any evidence to show that sewer-water does contain sulphuretted hydrogen in such large quantity as to be prejudicial and even fatal to animal life?—With a view of determining this question, I made the following experiments:—1st Experiment. A given quantity of Thames water, known to contain living infusoria, was added to an equal quantity of sewer-water; examined a few minutes afterwards the animalculæ were found to be either dead, or deprived of locomotive power and in a dying state. 2nd Experiment. A small fish placed in a wine glass of sewer water, immediately gave signs of distress, and after struggling violently, floated on its side, and would have perished in a few seconds, had it not been removed, and placed in fresh water. 3rd Experiment. A bird placed in a glass bell-jar, into which the gas evolved by the sewer-water was allowed to pass, after struggling a good deal, and showing other symptoms of the action of the gas, suddenly fell on its side, and, although immediately removed into fresh air, was found to be dead. These experiments were made, in the first instance, with the sewer-water of the Friar-street sewer; they were afterwards repeated with the water of six other sewers on the Middlesex side of the river, and with the same result, as respects the animalcules and fish, but not the bird; this, although evidently much affected by the noxious emanations of the sewer-water, yet survived the experiment.

50. Would you infer from these experiments that sewer-water, as contained in the Thames near to London, is prejudicial to health?—I would, most decidedly; and regard the Thames in the neighbourhood of the metropolis, as nothing less than diluted sewer-water.

51. You have just stated that you found sewer-water to contain much vegetable matter, and but few forms of animal life; the vegetable matter you recognised, I presume, by the character of the cells composing the several vegetable tissues?—Yes; as also by the action of iodine on the starch of the vegetable matter.

52. In what way do you suppose these various vegetable cells, the husks of wheat, &c., reach the sewers?—They doubtless proceed from the fœcal matter contained in sewage, and not in general from the ordinary refuse of the kitchen, which usually finds its way into the dust-bin.

53. Sewer-water, then, although containing but few forms of animal life, yet contains, in large quantities, the food upon which most animalcules feed?—Yes; and it is this circumstance which explains the vast abundance of infusorial life in the water of the Thames within a few miles of London.

54. Did you notice any other matters in sewer-water besides those

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which you have already mentioned?—I did; a black carbonaceous-looking matter, upon which the inky colour of sewer-water depends, and portions of an ochreous substance, having much resemblance to muscular fibre.

55. Do you know the nature of this black matter?—The abundance of this black substance in the worst examples of sewer-water strongly excited my attention; I have, however, formed no very exact conclusions respecting it, but I cannot help entertaining the suspicion that it is really carbonaceous, the carbon of the organic matters contained in sewer-water being precipitated by certain spontaneous chemical changes. A similar inky substance may frequently be stirred up from the bottom of old ponds containing organic matter.

56. Were you able to ascertain the nature of the ochreous matter contained in sewer-water?—This at first puzzled me a good deal; I have, however, I believe, succeeded in determining its nature in a satisfactory manner. I have already remarked upon its resemblance to muscular fibre, this as well as the absence of any marked results from chemical re-agents, have satisfied me of its organic nature, and the non effect of concentrated sulphuric acid proved to me that it must be an animal substance. This suggested the idea of submitting human fœcal matter to a microscopic examination, and in this I immediately detected the yellow matter in question in abundance, and in a more perfect state than it is usually met with in sewer-water. It is to it that the fœces mainly owe their colour. I conclude, then, from these several observations, that this yellow matter is really altered muscular fibre tinged with bile, the presence of which in it is shown by the action of nitric acid, which causes it to give out the pink tint characteristic of that fluid. I detected, moreover, in fœcal matter fragments of the husks and hairs of the down of wheat; these last bear some resemblance to animal hairs, but are much smaller.

57. Did you find sewer-water to contain much animal matter in a state of solution?—I did, a great deal.

58. Did it occur to you to submit sewer-water to a chemical as well as a microscopic examination?—It did; I detected in sewer-water the colouring matters of the urine and of the fœces, evidences of the presence of urea, (an effete animal substance,) much sulphuretted hydrogen, and several salts in large quantities, as chlorides, sulphates, phosphates, and carbonate of ammonia. The chlorides, sulphates, and phosphates, were in part, no doubt, derived from the urine and the carbonate of ammonia, in part from the decomposition of the urea of the urine. On evaporating drops of sewer-water on slips of glass, it was curious and interesting to observe the occurrence of forms of crystals common in the urine when thus treated. The addition of nitrate of silver to sewer-water produces a remarkable effect, the soluble organic matter, the sulphuretted hydrogen, the chlorides, and the phosphates are all thrown down, a fluid clear and colourless as pure water alone remains, containing principally the sulphates and the carbonate of ammonia.

59. Have you detected in Thames water the various matters which you have described as present in sewer-water?—I have, repeatedly; particularly the altered muscular fibre, the potato and other vegetable cells, and the husks and hair of the down of wheat.

60. Have you made any examination of the water of those companies which take their supply from the Thames?—I have.

61. And can you detect contamination by sewage in them?—I can, distinctly.

62. In what condition did you find the waters of those Companies which take their supply from the Thames?—Very bad indeed; some of them as bad as it was possible to conceive any waters used as a beverage could be; they abounding not merely with dead organic matter, but also with living animal and vegetable productions, *entomostraceæ*, *infusoria*, *annelidæ*, *conferveæ*, *desmideæ*, *diatomaceæ*, *fungi*, &c.

63. You did not, I presume, find the waters of all the Thames Companies equally bad and abounding to the same extent with animal and vegetable life?—No; for although the waters of all the Thames Companies were in a very impure state, yet marked differences were observable in the degree of impurity and in the characters of most of them. Thus the waters of those Companies which supply the Surrey side of the metropolis, as the Lambeth, Southwark, and Vauxhall, are in a far worse condition than those of any of the remaining Companies; the water of the Chelsea and West Middlesex Companies holds an intermediate position, although still very impure, while that of the Grand Junction Company, bad as it is, is yet the best of all the Thames Water Companies.

64. What were the characteristics of the water of the Lambeth Company?—The number of living productions contained in the water of this Company was very great indeed; but it was principally remarkable for the vast number of the Thames *paramecium* present in it, a circumstance explained in part by the fact that this Company takes its water from the river where those animalcules are very abundant, and in part, I believe, by the further fact, that it does not adopt any method of filtration, but delivers the water to the public in nearly the same state in which it is procured from the river.

65. What was the condition of the water of the Southwark and Vauxhall Company?—Equally bad, if not even still worse than the former; the living contents were not less abundant, although somewhat different in kind: thus while there were a great many Thames *paramecia*, there were also a considerable number of *actinophrydes* and *annelidæ*, clothed with spine-like hairs; the former being most abundant in the water supplied to the district of Southwark, and the latter in that furnished to the inhabitants of Vauxhall. It is to be remarked that the *actinophrydes* occur likewise in the water of the Lambeth and Chelsea Companies, as well as in that supplied to Vauxhall, but not in the same numbers.

66. How do you account for the water furnished by the same Company thus differing in its living productions?—Although now united into a single Company, at one time the Southwark and Vauxhall formed two distinct Companies; and in this circumstance we probably find the explanation of the differences indicated by the microscope. The fact of their having been once distinct implies the possession of separate works and reservoirs, and probably a different system of management. I would here observe that the many forms of infusorial life encountered in the waters of the Metropolitan Companies which derive their supplies from the Thames, although the *paramecium*, so

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67. You have stated that you detected matters connected with sewage in some of the Thames Companies, what was the nature of these matters, and in which of the Companies' waters did you detect them?—I have detected on several occasions, in the waters of the Lambeth and Southwark and Vauxhall Companies, matters connected with sewage, as the fragments of muscular fibre tinged with bile, black carbonaceous matter, and portions of the husks and hairs of the down of wheat, cells of potato, granules of starch, &c.

68. What was the state of the water of the Chelsea Company?—Better than that of any of the preceding Companies. The same forms of infusorial life were, however, present in it, but in greatly reduced numbers, a circumstance explained by the fact that this Company adopts a more efficient process of filtration, but one still not entirely or sufficiently effective, since living productions, and especially bunches of brown ova cases, are present in it after filtration.

69. And the West Middlesex Company, how have you found its water, as delivered to the houses?—Less free from living organic matter even than that of the Chelsea Company; it contains, amongst other productions, numerous Thames *paramecia*.

70. And the water of the Grand Junction Company?—Notwithstanding that this Company filters its water, I have yet found it to contain a considerable number of living animal and vegetable productions, but not in general the Thames *paramecium*, which is accounted for by the fact that this Company takes its supply from just above the usual limit of the distribution of this animalcule; the water of this Company, therefore, loses one of the chief characteristics of excessive contamination by sewage, and approaches more nearly in its condition that of rivers in general.

71. What have you found to be the state of the waters of those Companies which have a source of supply different from the Thames?—Very bad, but still their condition has been much better than that of all the Thames Companies, with the exception of the Grand Junction.

72. What was the condition of the water of the New River Company?—I found in it a few *entomostraceæ* and *infusoria*, but a great many *diatomaceæ*.

73. How do you account for the abundance of *diatomaceæ* present in this water?—In all slowly running rivers the *diatomaceæ* are very abundant; now New River water is not as is generally supposed spring water, but is composed in great part of water derived from the river Lea, and is conveyed to London at a very slow rate by means of a long and open canal, a circumstance which is therefore highly favourable to the development of the *diatomaceæ* especially, as well as other forms of microscopic life.

74. What was the state of the water of the East London Company?—It presented many of the characters of New River water, but also a greater number of *infusoria*, which is probably to be explained by the circumstance that the Lea is exposed to some extent to contamination by sewage.

75. As to the water of the Hampstead Company?—The water of

this Company abounds with *entomostraceæ* and *infusoria* of the genera *aneurea*, *brachionus*, and *peridinium*, the species being similar to those contained in the large ponds from which this Company draws its supplies. There can, consequently, be no doubt whatever as to the source of the animalcules contained in the water of the Hampstead Company as supplied to the public.

76. And the Kent Company?—The water of this Company contains a considerable number of *infusoria* and *diatomaceæ*, and presents an average example of the waters of small rivers, such as are not protected from the public, the banks of which are not kept free from weeds, and into which are poured the contents of dykes and ditches, &c.

77. Are these several results founded upon repeated examination?—Yes; upon repeated examination. I have made several hundred microscopic examinations of water, of the principal results of which I have in general preserved notes. The water of the several Companies submitted to examination was obtained from the service pipes of different cisterns; it was therefore in the precise condition in which it was supplied to the public. It is to be remarked, that the above details and descriptions refer to the condition of the water during the winter and early spring months; in the warm weather of summer the state of the water would, no doubt, be much worse, the lower forms of animal and vegetable life would be more abundant, and the kinds in many cases different.

78. Will you state the determining causes, whether ingredients in the waters, or nature of the aqueducts, reservoirs, &c., or other circumstances on which the development of the different classes of animalcular and vegetable productions, in your opinion, depends?—The circumstances specified in the question, as well as some others not mentioned, all influence and determine, not merely the kind but also the quantity of animalcular and vegetable life present in the waters of the several London Companies. Thus “ingredients in the waters,” as the various organic matters connected with the sewage contained in the Thames, determine the presence in Thames water of certain forms of infusorial life and the abundance of other forms, as the *paramecia*, *vorticellæ*, *actinophrydes*, *oxytricæ*, *uvellæ*, &c. The same ingredients determine also, it is most probable, the presence of the *annelidæ* in large numbers as Thames water, as also undoubtedly the *fungi*, which generally abound wherever organic matter is abundant. The comparative absence of vegetable life, especially of the coloured and green species, in Thames water near to London, is remarkable, and is accounted for probably partly by reference to the deleterious quality of the water, but is the result principally of the incessantly agitated condition of the river, occasioned by the numerous steamers which are constantly moving up and down on its surface. Now, as is the water of the Thames, so must, to a greater or less extent, be that of the water of those Companies which derive their supplies from the Thames; and we have already seen that this is really the case, and that the water of all of these Companies differs only from Thames water according to the particular part of the river from which its supply is derived, and the extent of the processes of purification adopted; thus the water of the Lambeth Company, taken from the part of the river where the Thames *paramecium*

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is very abundant, and no process of filtration being adopted, differs but little in any respect from Thames water near to Lambeth, and swarms like it with *paramecia*. The water of the Chelsea Company, inasmuch as it is filtered, is freed to some extent of its impurities; but yet a microscopic examination renders sufficiently manifest the nature of its source, and in it we likewise discover the particular species of animalculæ so characteristic of Thames water. In the water of the West Middlesex Company, again, we meet with numbers of the Thames *paramecium*, as well as other *infusoria*, but not nearly in the same proportion as in the Lambeth or Southwark and Vauxhall Companies, because these do not exist in the part of the river from which it draws its water in nearly the same quantities as at Lambeth. Again, in the water of the Grand Junction Company the *paramecium* is almost lost.

Other differences in the kind and quantity of animalcular life depend not merely upon temporary storeage in reservoirs, but also upon the condition of these as to cleanliness; if they contain much mud or sediment, and accumulation of organic matter, then we may look for the presence, in abundance, of minute *annelidæ* or worms, and it is probable that this is really the explanation of the great numbers of these creatures present in the water supplied to the Vauxhall district.

Then again we have seen that all small rivers, canals, and aqueducts abound with *diatomaceæ*, and hence it is that we find so many of these productions in the water of the New River, East London, and Kent Companies, especially the first.

It has been shown, also, that large pieces of water are favourable to the development of the *entomostraceæ*, and certain of the larger *infusoria*, owing, probably, to the absence of any decided stream or current in them, the waters being, in general, still and tranquil; and herein is the reason of the abundance of these animalculæ in the water furnished by the Hampstead Company.

The above are some of the principal circumstances favouring the development of different kinds and quantities of animal and vegetable productions in different waters; others are met with in the degree of exposure of the water, and the length of time it has been retained in the reservoir; these two circumstances operating in combination would determine, not merely an increase in amount of the living contents of the water, but would, probably, cause certain species to obtain a predominance.

79. Have you made any examinations of cistern water?—I have, many. A cistern is a small reservoir, and has all the faults of reservoirs; the water contained in it is generally exposed to light, air, and the sun, and the dead and living organic matter, as in the case of the reservoirs, too often goes on accumulating from day to day, the former seriously contaminating, by decomposition, the purity of its water: the living organic productions present in the water of cisterns resemble those of the water of the company by which it is supplied; certain forms, however, become developed in the water of cisterns with great rapidity, as the *entomostraceæ*, especially *cyclops*, *quadricornis*, *lynceus longirostris*, *daphnia quadrangula*, *infusoria*, *conferveæ*, and *diatomaceæ*; the *entomostraceæ*, and some of the *infusoria*, swim freely about in the water, while the *conferveæ*

and *diatomaceæ* either adhere to the sides, or else fall to the bottom of the cistern, together with the grit and dead organic matter, forming an ever increasing mass, which is stirred up on each renewal of the water only to subside in still greater quantity, until after the lapse of weeks, months, or even years, some fortunate accident, or frequently the offensive and putrid state of the water causes the cistern to be cleaned, and a removal of the putrescent and noxious matter. On making inquiries as to the frequency with which cisterns are cleansed, I was astonished to find how generally they are neglected; a neglect which is to be explained partly by ignorance of the necessity which exists for repeated and careful cleansing, and partly by the inconvenient and absurd position in which cisterns are very generally placed, mounted high up, frequently just over the privy or closet, and often requiring ladders to reach them; but the evils of cisterns are not merely aggravated by neglect and bad management, there are faults of construction connected with them; thus the bottom is usually level, and the tap inserted about two inches above this level, leaving a space for the continued accumulation of grit and dead and living organic matter; this evil might be obviated by having the cistern of a rounded form at the bottom, the discharge pipe issuing from the centre. Lastly, the material of cisterns is bad; they should be made of glass, earthenware, or marble.

80. You have already given the results of your examination of New River water as delivered to the houses, but what difference did you find in the water from one end of the river to the other?—The water in the little stream or ditch which flows into the New River Head, and which assists in supplying it, is in a very bad condition, and abounds in *infusoria* and *algæ*, especially species of the genus *rotifer* and the *diatomaceæ*. The state of the water in the head itself, inasmuch as it receives all the water from the feeding ditch, cannot be much more satisfactory; the margins of the pool or basin forming the head are covered with *algæ*, rising up into the water like clouds, and affording a nidus for the shelter, growth, and development of the *entomostraceæ*, *infusoria*, &c. The canal or river itself is at the present time* in a much better state than I have ever seen it before, but the quantity of *oscillatoreæ* and *diatomaceæ* which float on its tranquil surface during the warm weather of summer is immense, and must seriously affect the condition of the water. At Cheshunt the New River Company has a well worked by a steam-engine, and two reservoirs; the one of these reservoirs at least contains something more than pump-water, it being fed by a small stream, nearly dry in summer, but which in rainy weather contributes as well as the pump a fair supply of water. Well, the state of the water in these reservoirs at present is not very bad, but few *entomostraceæ* and *infusoria* being yet contained in it; this is accounted for by the fact that these reservoirs have very recently been cleaned out, and certainly the operation was much wanted, as I was given to understand that it had not been once performed before since the reservoirs were made, nearly twelve years since. The cleaning out of these reservoirs occupied nine weeks, employed thirty horses, and not a few labourers; the matter

* Early in May.

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removed consisted of a black muddy substance of an offensive smell, and similar in nature to that contained at the bottom of old ponds, and also to that which has recently been taken out of the Serpentine; this black mud contains much organic matter, of which fact those who removed it seem fully aware, as it has been spread over a field near to the reservoirs, and to the fertility of which it will no doubt greatly contribute. Some years ago the waters of the Cheshunt reservoirs were in a less pure state than at present, and were a frequent resort of mine, for on turning to my "History of the British Fresh-water Algæ," I find them given as the habitats of several species. Just below the head, the stream of the New River is joined by a second stream, apparently larger and more considerable, which comes from the River Lea. New River water is therefore a mixture of ditch, spring, river, well, and possibly in some cases of Thames water, as the New River Company has a communication with the prolific source of London water supply, the Thames, at Broken Wharf, Upper Thames-street.

81. Does the number of living productions in New River water equal those you found in the Thames, with the exception of those which you think are connected with sewage?—I should say that it contains as many living productions as Thames water does, taken above Richmond.

82. What was the condition of the water of the Lea?—I am inclined to think that the water of the Lea contains a larger number of *infusoria* than that of the New River. I examined its state more particularly in the canal of the East London Water Company, and found a very great many *diatomaceæ* and *infusoria*, principally of the genera *exilaria*, *diatoma*, *asterionella*, *coleps*, *oxytrica*, *bursaria*, and *amphiliptus*. Now it is from this canal that the East London Water Company professes to derive all the water which it requires, and yet it has a communication with the Lea, below Lea Bridge, at Old Ford, near to Stratford, and within the influence of the tide of the Thames, the water of which is still further contaminated by the many impurities of Blackwall Creek. I may here be permitted to state that further particulars in reference to the source, &c., of the River Lea, among other facts connected with the subject of water in general, will be found in a little work which I have recently published, entitled "A Microscopic Examination of the Water supplied to the Inhabitants of London. Illustrated by coloured plates."*

83. What are the indications as to the waters of the Wandle?—The river Wandle has a double origin; the one in a large pond situated in the town of Croydon, the other in springs at Waddon, near to Croydon. The water of the inner, or first spring, is remarkably free from living organic matters; that of the second spring contains numerous species of the lower forms of vegetable and animal life, and this is accounted for by the weedy and uncleaned condition of the borders of the spring or pond, while that of the third spring is still more contaminated with vegetable and animal life, it not merely being in a foul state, but receiving a small stream, which carries with it various impurities from the pond at Croydon. The pond situated in the middle of Croydon receives much of the sewage of the town, the refuse of gas

* Highley, 32, Fleet-street.

works, a tan yard, and, I believe, also of a knacker's yard; its water teems with algæ and infusoria of the most impure kinds.

84. In what state was the water at Beddington, below Croydon?—It was found to contain many of the same forms of animal and vegetable life noticed in the pond at Croydon, and the same productions could be traced, by means of the microscope, at various points lower down the stream, even to Wandsworth, where it joins the Thames.

85. Have you tried the deep wells of London?—I have; the waters of the deeper wells are, in general, very free from living organic matter.

86. Have you made any investigations on the subject of the aeration of water?—I have.

87. To what is the presence of aeriform substances in water attributable?—To a remarkable power possessed by water to absorb and condense many of the gases in contact with or near to it, and which power is so great as to enable it to take up many times its own volume of certain gases.

88. What are the circumstances which regulate and determine the actual amount of the gases present in water?—The degree to which the air is charged with these gases, and the temperature of the water; the gases usually present in the air are ammoniacal gas, nitrogen, carbonic acid, and oxygen; the greater the quantity of these in the air, and the lower the temperature, the larger will be the quantity of gases absorbed. It is to be observed, however, that certain gases are sometimes present in water, as the sulphuretted, carburetted, and phosphuretted hydrogen gases, and which are not derived, in general, from the air, but from decomposing substances contained in the water.

89. Can you refer to any simple experiment proving the absorption by water of aeriform substances?—If water deprived of all gases, as distilled water, be exposed to the air, and tested after the lapse of a day or two, it will be found to have taken up an appreciable quantity of carbonic acid and oxygen; the same will happen if water be placed under a bell-jar, in contact with sulphuretted hydrogen; breathing through water is also sufficient to saturate it with carbonic acid.

90. Does the amount of oxygen contained in the atmosphere vary much?—Not so much as might be supposed; that is to say, the air of a large town has been found to contain nearly as much oxygen as that of the open country; the injurious effects on health of the air of cities is due, therefore, not so much to the deficiency of oxygen as to admixture with many deleterious contaminations; this nearly uniform composition of the atmosphere in town and country is the result of the operation of the law of the diffusion of gases, a law by which hundreds of lives are probably daily saved; in confined spaces, however, as in rooms, theatres, assemblies, where the law could not come freely into action, the quantity of oxygen present would be greatly deteriorated by respiration.

91. The quantity of oxygen present in water is, therefore, in your opinion, not subject to any great variation?—Not at *equal* temperatures; at *unequal* the variation is very great.

92. Is the variation of the temperature of water under common circumstances sufficient to occasion differences in the quantity of gases present; as, for instance, when it is exposed to the sun or the warmth

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of a room?—Decidedly so, the warmth of the sun's rays, or of a close room, are quite sufficient to occasion the expulsion of the greater part of the oxygen and carbonic acid present; and by boiling, the whole of these and other gases may be driven off.

93. The exposure then of water used for domestic purposes to a high temperature is prejudicial to its salubrity?—Yes, unquestionably; the oxygen and carbonic acid is thrown off, and hence the flatness and insipidity of the water: the oxygen expelled from water by the heat of the sun is, however, re-absorbed during the night, when the temperature is low.

94. Does the quantity of carbonic acid present in most water vary much?—Yes, a good deal; I have instituted a variety of experiments, intended to prove the absorption by water under more or less common circumstances of carbonic and in different proportions. These experiments are, however, not yet completed.

95. You have mentioned sulphuretted hydrogen as amongst the gases occasionally met with in water, have you detected it in any water now used as a beverage?—I have repeatedly, in Thames water, in the neighbourhood of the bridges; indeed on no occasion have I failed to find it.

96. What was the method of proceeding adopted?—I added to a wine glass of water a few grains of acetate of lead; this, after an hour or two, formed a precipitate at the bottom of the vessel of a brownish colour, a sulphuret of lead; in order to render the tint of the precipitate more evident, it is advisable to add a little of the lead to some water not suspected to contain the gas in question, and to contrast the two. The sulphuretted hydrogen might still be unequivocally detected in many cases in the Thames water, even after filtration.

97. The presence of sulphuretted hydrogen in Thames water, near the bridges, is due to the decomposition of the organic matter so largely thrown into it from the sewers?—Yes.

98. Have you found water to absorb this gas from the air under any circumstances?—I have detected it in water placed within the influence of the emanations of a privy, from which, as is well known, large quantities of this gas are given off, especially in the hot weather of summer. It, therefore, becomes very probable that the water of cisterns placed near privies, or over closets, as they too frequently are, is sometimes contaminated by sulphuretted hydrogen.

99. Is not this gas highly prejudicial to animal life?—Yes, very much so, and in large quantities even fatal. There can be little doubt also, but that, in the quantity in which this gas is contained in Thames water, it exerts an injurious effect on health, whether it be directly introduced into the stomach in the water drank, or whether it be received into the lungs in the vapour of Thames water. At all times, but especially in hot weather, a large quantity of water rises by evaporation from the river; this is rapidly diffused throughout the atmosphere of the whole city, and in this way the gas in question reaches the lungs of every inhabitant. This consideration forms an additional reason why sewage should not be discharged into the Thames near London.

100. What is the effect of filtration upon the aeriform substances contained in water?—The general effect is to remove a certain portion of

the gases ; there are, however, particular effects according to the filtering media employed, and the nature of the gases present.

101. How do you account for the fact that water taken high up the Thames, before it is mixed with the filth resulting from extensive traffic on the river, and the sewage of large towns, is brisk and clear, while if obtained lower down it is flat and dead?—If obtained high up the river, its comparative freedom from organic and other impurities accounts for its clearness and much of its freshness ; its briskness depends upon the amount of carbonic acid gas which it holds in solution ; if procured low down the river, near London, its extensive admixture with, and contamination by, sewage, decomposing organic matters, and deleterious gases, sufficiently explains the dead and turbid character of the water.

102. Is a stagnant condition of water, or one of motion, favourable to aeration?—To this question I am scarcely able to reply very satisfactorily. I believe, however, that motion greatly promotes the aeration of the water. Thus, if we merely breathe upon the surface of a tumbler of distilled water, a much longer time will be required to impregnate the liquid with the carbonic acid gas contained in the breath than if we were to pass a current of respired air through it by means of a little glass tube. The motion of water agitated by wind or storms of rain, &c., is of a somewhat similar character, and is probably attended by increased aeration.

103. Upon what does the smell which impure water frequently possesses depend?—Generally upon the presence of vegetable and animal matter in a state of decomposition, and which, in that condition, gives rise to the formation of sulphuretted and phosphuretted hydrogen gases, both of which have a peculiarly offensive odour.

104. Have you been able to detect any unpleasant odour in the water of the Thames?—I have on several occasions detected in Thames water from the neighbourhood of the bridges a very decided smell of sulphuretted hydrogen ; and in other instances the water has possessed a strong fæcal odour.

105. Have you noticed any unpleasant taste in water containing decomposing vegetable and animal matter?—I have ; on several occasions.

106. From the river the water is often carried into a court or alley, and placed in a tank or tub, sometimes near the privy, when it quickly begins to smell disagreeably ; the same is the result if it be kept in a room where persons are crowded together. To what is this attributable?—To the decomposition of the organic matter contained in the water, favoured by increased temperature, and to the direct absorption of sulphuretted hydrogen, ammonia, and vitiated air, the last especially, in a close room.

107. What are the effects of the respiration of animals and plants upon the composition of the atmosphere, and upon the aeration of the water?—The general effect of the respiration of animals which live on the earth is to occasion the deterioration of the air by its admixture with the carbonic acid, so largely present in the breath or expired air ; while that of the respiration of terrestrial vegetables is precisely the reverse, they absorb the carbonic acid of the air, fix the carbon in their own tissues, and yield up the oxygen ; thus the general effect of the

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respiration of plants is to counteract the tendency to atmospheric deterioration occasioned by the respiration of animals. Now the same law holds good with respect to the respiration of the animals and vegetables present in water, the tendency of the one is opposed by that of the other, and hence we find that in water, as well as on the earth, animal and vegetable productions are constantly associated and naturally dependent upon each other.

108. Have you made any experiments upon the subject of filtration?—I have, a considerable number.

109. Will you be good enough to state their nature?—I would observe that filtration is an operation which is carried on in nature on a large scale, and in a very effective manner; looking upon the surface of the earth, and reflecting upon what passes there, many instances of filtration present themselves to our notice; it is by filtration that the water which falls upon the surface of the earth in dew, showers of rain, or storms of hail or snow, makes its way into the soil which it vivifies; it is by filtration or percolation that this water passes from the soil into the cellular tissue of the plant which it pervades, imparting to it freshness and vigour; it is by this operation that the river as it flows along fertilizes the adjacent fields and pastures; the water of the pure well, or that which gushes from the spring, is filtered water, and man in his attempts at filtration does but imitate in a less effectual manner, and on a much smaller scale, a natural operation. Now filtration is of two kinds, mechanical and chemical; sometimes both are in action at the same time, and this is generally the case when water passes through soils. I first directed my attention to the mechanical properties of filters, experimenting with the following substances; namely, coarse and fine bibulous paper, wool, sand, vegetable charcoal, animal charcoal, mild and strong clays; it is proper to state, that the water employed as a test was green pond-water, the colour of which proceeds for the most part from the presence of myriads of *Infusoria*, of the genera *Microglena*, *Cryptoglena*, and especially *Euglena*.

110. Then your first experiments had reference to the removal, not of solid and inorganic particles, but of organic matter?—Yes, it was to this point that my inquiries were particularly directed, and in the first instance they were limited to living organic productions, as the *Infusoria*, &c. I will now proceed to state the results:—The water passed through *fine and coarse bibulous paper*, retained a very evident green tinge, deeper through the coarse than the fine paper, and examined through the microscope was found to swarm with *Infusoria*. Filtered through *sand*, it possessed an evident green colour, and contained multitudes of animalcules, some of large size. Passed through three different *patent filters*, it also came out retaining some colour and opacity, as well as numerous *Infusoria*. (In testing the powers of a filter, it is necessary that the first quart of water which passes should be rejected, as much of this, in general, does not consist of the water last placed in the filter, but of that retained in the filtering media from the previous filtration.) After filtration through *vegetable charcoal* the water entirely lost its green hue, but possessed a certain degree of opacity, and examined with the microscope the smaller animalculæ were to be detected in great numbers. Passed through *animal charcoal* the water came out bright and transparent, without colour or opacity, and no

animalcules could be discovered in it. Through *loam* the water was still perceptibly green, and contained the animalcules in great abundance. Filtered through *mild* and *strong clay*, the water was nearly as clear and bright as through the animal charcoal, without trace of *Infusoria*. It is now to be observed that in all cases in which the *Infusoria* passed the filter, they were found, on examination with the microscope, to be in a living condition. In those cases in which they were entirely retained by the filter, the animalcules did not penetrate into its substance beyond the depth of an inch, or at most two inches. It may be objected to these experiments, that the green water employed was not fair test water, inasmuch as filters are not in general required to purify such water; this objection is more specious than real, for all water contaminated with *Infusoria*, contains some of the smaller kinds of animalcules, and the ova of all; these, therefore, are equally liable to pass the filter as those of the green pond-water, and that they do so is shown by the results of the filtration of Thames water given hereafter.

111. Are we to understand from these experiments that by filtration through clay and animal charcoal the *Infusoria* were entirely removed?—They were so far removed that none could be detected by means of the microscope; however, I took the precaution to preserve for the period of a fortnight some of the filtered water, and on examination at the expiration of that time I again discovered the same species of *Infusoria* as were present in the water previous to filtration; this shows that although the animalcules themselves were removed, yet that their ova were not entirely so.

112. Did it occur to you to filter Thames water as procured from the river, near the bridges?—It did; some Thames water was passed through one of Lipscombe and Co.'s filters. *Before filtration*, the water was dirty and opaque, containing much dead organic matter and grit, as well as numerous *Infusoria*, especially the Thames *Paramecium*, *Diatomaceæ*, and filaments of *Fungi*. It also furnished distinct evidences of the presence of sulphuretted hydrogen. *After filtration*, it came out clear and bright, without visible sediment or discoloration; examined with the microscope, nearly all the dead organic matter and grit was found to have been removed, and comparatively but few living productions were present: three or four *Paramecia*, *Oxytrichæ*, and minute *Naviculæ*, with fragments of filaments of *Fungi*, and numerous ova and monads of small size. No sulphuretted hydrogen.

113. Were the animalcules in the green pond-water very small?—Yes, many of them exceedingly minute; in fact the smallest known.

114. It may be safely assumed, I suppose, that those substances which most effectually arrest living organic matter, will intercept in an equally efficient manner dead organic particles?—Undoubtedly; I would now observe, that I put the mechanical powers of the different filtering media enumerated above to a still severer test than that of the green pond-water, thus: I passed through each a portion of fresh milk; those who are acquainted with the microscopic constitution of this fluid, will know how admirably it is fitted to serve as a test liquid for filters; the butter is contained in milk in the form of globules of variable sizes, but some of which are exceedingly minute, and it is to the presence of

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these that milk owes its opacity and colour: except from the animal charcoal and the mild clay (the strong was not employed), the milk as it escaped was observed to retain much of its colour and opacity, and this was the case even with that which came away from the vegetable charcoal and the patent filters; that, however, which flowed from the animal charcoal and mild clay, was nearly but not quite as transparent as pure water, and on microscopic examination the globules of butter could not be detected; these were all retained on the surface of the filters, where they formed a thick stratum of cream.

115. Much has been said upon the subject of filters not retaining the fluid or soluble organic matters present in some liquids and in impure waters; have you directed your attention to this point, and can you state from observation or experiment whether filters do or do not intercept such fluid organic substances?—I have made many experiments in order to determine this point; I first passed some recent human urine through vegetable and animal charcoal, loam, and mild clay; passed through the vegetable charcoal, the urine still possessed some colour and a faint urinous smell; through loam the colour was deeper and the smell stronger, while through animal charcoal and clay the urine was as clear and as free from colour or smell as the purest water; tested for the peculiar colouring matter of the urine, this was abundant in the urine from the loam and vegetable charcoal, with but faint indications only of its presence in the animal charcoal and clay, least of all in the former; tested for urea, (an effete animal substance,) this was found to be present in abundance in all the examples of urine; the crystalline substance, formed with nitric acid, on the evaporation of a given quantity of the urine, being beautifully clear and colourless in that from the animal charcoal; chlorides and sulphates were all present in each case. I next tested the serum of milk filtered through animal charcoal and mild clay, and here I found the caseine or cheese in abundance; it is thus evident that fluid animal substances are not entirely arrested by even the best filters. I will now show that fluid vegetable substances are likewise not intercepted, or rather that some filters themselves yield to the liquid filtered fluid vegetable matter; the first portions of water passed through loam are usually beautifully clear and colourless, but after a time, and as soon as the soil becomes thoroughly saturated, the water is often turbid, and of a deep brown colour. Now, if lime-water be added, even to the clear and colourless water, in a few minutes a change in the liquid will be observed; it will become of a bright brown, almost gold coloured, and finally it will deposit a brown sediment, which is the lime in combination with the vegetable substance.

116. Have you instituted any experiments with the view of determining the effect of filtration upon the aeration of water?—I have made some observations in order to ascertain the power possessed by certain filters to absorb and remove sulphuretted hydrogen and carbonic acid from water. Paper, sand, and wool, being for the most part mechanical in their action, it was not necessary to experiment with them. Sewer-water, holding in solution a large quantity of sulphuretted hydrogen and of organic matter, emitting an odour in a high degree offensive, was passed through the following substances:—

Vegetable Charcoal.—From this it came out free from smell, and colourless, yet evidently somewhat opaque; tested for sulphuretted hydrogen, this gas was not found.

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Animal Charcoal.—Through this the water escaped clear and brilliant, without the slightest opacity, and showing no traces, on the application of tests, of the presence of sulphuretted hydrogen.

Patent Filters.—Passed through these, the water passed with a slight tint of colour and opacity only, but furnished evident traces of the presence of the gas in question.

Loam.—From this the water came out in scarcely so pure a condition as from the filters, and also contained sulphuretted hydrogen.

Mild and Strong Clays.—Through these the water passed as clear and transparent as through the charcoal, but yet was found to furnish distinct evidences of the presence of the gas. The sewer water, tested for sulphuretted hydrogen before being passed through a filter, gave with lead a dark brown precipitate; while, after having been filtered through the patent filters, loam, and clay, the colour of the precipitate was of a light brown. It is, therefore, evident that all the above filtering media are, to a greater or less extent, chemical; and that, while some of them absorb the whole of the sulphuretted hydrogen, others retain only a portion of it. Most of the patent filters are made with a certain amount of charcoal, and hence their chemical properties. Now, although the water employed in these experiments was sewer water, yet the same proportional effects would follow the use of any water containing sulphuretted hydrogen. Again, Thames water, known to contain sulphuretted hydrogen, was passed through the same media, and when tested for the gas it was found in all the filtered waters, except those which had come through the animal and vegetable charcoal. When acetate of lead was added to the water filtered through loam, a precipitate was obtained somewhat similar to that noticed on the addition of lime water, and indicative of the presence of organic matter.

117. What experiments did you make with the view of ascertaining the effects of filtration upon the amount of carbonic acid present in water?—Water highly saturated with carbonic acid was passed through the same media as the sulphuretted hydrogen. After filtration through animal and vegetable charcoal, a trace only of carbonic acid was to be discovered; the water filtered through loam and mild clay contained the gas abundantly, but yet in much less quantity than previous to filtration. After passing through the patent filters the water gave distinct evidences of the presence of carbonic acid, but in less amount apparently than that from the loam and clay.

118. Are you acquainted with the effects of filtration upon the oxygen of the water?—I am not; it is most probable, however, that a portion of the oxygen is removed at the same time with the carbonic acid of the water.

119. Did it suggest itself to you to try the effect of filtration upon the amount of carbonic acid present in any water in common use, as Thames water?—I passed Thames water through animal and vegetable charcoal, a patent filter, loam, and mild clay. Much of the gas was abstracted by the animal and vegetable charcoal and the patent filter, but nearly the whole of it, as well as the carbonates of the water, were removed by the loam and mild clay, and by the loam in a more com-

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plete manner than the clay; the same discoloration was to be observed in the water from the loam, to which lime was added, as previously noticed and remarked upon.

120. Have you made any observations on the power of soils, and other substances, in removing salts from water?—I have not extended my observations to this branch of inquiry; I may be permitted to observe, however, that the majority of the results of filtration through soils are determined by and dependent upon the general laws of chemical affinities, rather than upon any peculiar and absolute powers dwelling in particular kinds of soil; thus the results of filtration through soils are generally to be explained by the chemical constitution of the soils themselves. Water passed through animal charcoal will bring away with it some of the phosphate of lime present to the amount of 10 per cent. in that substance.

121. Will you now, as briefly as possible, enumerate the results which appear to rest upon the various experiments on filtration which you have detailed?—From the results of these experiments the following conclusions may be safely deduced:—1st. That bibulous paper, sand, wool, and loam, are bad mechanical filters; 2nd. That vegetable charcoal is by no means a perfect one; 3rd. That the mechanical powers of patent filters are in general but limited; 4th. That animal charcoal, mild and strong clay, are nearly perfect as respects their power of mechanically retaining the solid matter, dead and living, found in even the worst descriptions of water; 5th. That inasmuch as the animalcules pass through some media in a living state, that these, including loam, do not exert any chemical effect upon living organic particles; 6th. That soluble organic matters, either animal or vegetable, are not in general removed even by the more perfect methods of filtration; 7th. That some soils, as the loams which contain a large amount of dead and decaying organic matter, principally vegetable, give up to water fluid organic substances; 8th. That the effect of filtration on the aeration of water is to lessen the quantity of aeriform substances contained in it; 9th. That for the removal of sulphuretted hydrogen, charcoals, especially the animal, are best; 10th. That animal and vegetable charcoal, loam, and mild clay, all remove the greater part of the carbonic acid present in water, the two latter abstracting likewise its carbonates.

122. Did you notice any great difference in the relative speeds with which the several fluids passed the filters?—I did, very great differences; the worst mechanical filters are in general the quickest filters, while the best are the slowest in their action; of the more perfect filters, animal charcoal is the quickest.

123. How are these differences to be explained?—By reference to the size of the integral particles composing the various filtering media; thus the microscope clearly shows that the constituent particles of the best filters are very small in size, while those of the worst are larger. It is worthy of observation, however, that the absorbing power of substances for gases is to a great extent independent of size; thus coarsely powdered vegetable charcoal will take up gases equally well, if not better, than when reduced to a very fine state of division.

124. The conclusion therefore appears inevitable, from the results of your numerous observations on filtration, that although the grosser

impurities of water may be removed by this process effectually carried out, yet water highly contaminated with organic matters, especially fluid, cannot be wholly purified by filtration?—Exactly so; and I would observe that there is great reason to believe that the fluid impurities of Thames water within some miles of the metropolis are very great in amount and variety.

125. Would you now describe the nature of the apparatus employed in your experiments?—The different filtering media were placed in glass cylinders of about two inches in diameter, each holding one pound and a quarter of material, and which formed a stratum of from nine to ten inches in thickness; increasing the thickness of the strata, which might be done to any extent, would of course modify the results obtained considerably.

126. Then we may state it as a conclusion that the microscope does display differences in water which chemistry cannot detect?—The microscope undoubtedly develops facts which chemistry could never arrive at, and which it is not the province of that science to deal with.

127. Especially as regards the salubrity of the water, for while chemistry discovers what makes water hard, or its saline and mineral constituents, it fails to show the nature and varieties of the organic matters contained in it, and upon which the deleterious qualities of water in general depend?—Chemistry does not inform us of the species and modes of life of the various creatures found in river and many other waters.

128. Is there not a great amount of animal life in water which can hardly be said to be inconsistent with the general good health of those who drink it?—I should say, decidedly not; all living matter contained in water used for drink, since it is in no way necessary to it, and is not present in the purer waters, is to be regarded as so much contamination and impurity, is therefore more or less injurious, and is consequently to be avoided. There is yet another view to be taken of the presence of these creatures in water, viz., that where not injurious themselves, they are yet to be regarded as tests of the impurity of the water in which they are found.

129. Then you think that the importance of the presence of these species is less from their actual consumption than from their being indications of the presence of animal and vegetable matter in a state of decomposition, and on which they feed?—Yes; such is, no doubt, the correct view to take of the presence of the majority of living productions found in water; it is doubtful, however, whether some of them may at all times be consumed with impunity.

130. What are the observed effects of the consumption of the various forms of animal and vegetable life present in water on health?—The fact of the existence in large quantities of living productions belonging to several distinct divisions of the organic world, and for the most part entirely invisible to the common eye in the waters in general use, was not, I believe, generally known until announced by myself in the pages of "*The Lancet*" some weeks since; it is, therefore, scarcely to be expected that there should as yet have been made many observations tending to show the effects of their consumption upon health; nevertheless, we are not altogether without sufficient data upon which to found an opinion; thus the organization and mode of

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life of many of these productions, as the *entomostraceæ*, most of the *infusoria* and *algæ*, are such as clearly to unfit them for any prolonged existence in the human stomach and intestines, and there is no question but that when introduced therein they speedily die, the digestible portions of them being assimilated; but whether this is the case with the *fungi*, the *annelidæ*, and certain *infusoria* and *algæ*, admits of considerable doubt. It is a well ascertained fact that the *fungi* have the power of attacking and even proving fatal to many vegetable and the lower forms of animal life. I may here refer to certain experiments which I made some years since to test the aggressive and parasitic powers of *fungi*. Many fruits, such as apples, pears, and peaches, and several vegetables, as the lettuce, vegetable-marrow, potato-haulm, &c., were inoculated with the sporules of *fungi*; the result of this was that they all became speedily diseased, and in a few days many of them entirely disintegrated and destroyed. It is to be observed that these experiments were made on healthy and growing fruits and vegetables; the former were still on the trees, and the latter rooted in the earth. In the softer fruits, as the peach and some kinds of apples and pears, the effects of the inoculation became visible in less than 24 hours, a dark spot, like that of mortification, first appearing, and this gradually extending in all directions until the fruit became completely disorganized. There are now also many recorded cases in which *fungi* have attacked the living animal organism, including even man himself; the disease, muscardine, which occurs in the silk-worm and many other animals of the same class, as well as the peculiar softening which the tails of fish confined in glass globes frequently undergo, is attributable to the growth within the tissue of the animal of ramifying filaments of *fungi*. Again, *fungi* have been noticed growing on ulcerated surfaces in the human intestines in cases of fever; they have likewise been observed in certain affections of the skin, and in discharges from the stomach, bowels, bladder, and vagina.

With respect to *annelidæ*, it is commonly known that several species of worms live in the human intestines, and even grow and multiply there, greatly to the detriment of health, and it is difficult to avoid the conclusion that they are really introduced from without, either in the water, or through the medium of the food.

Animalcules widely differing from each other have also been observed to occur in the human organism in connexion with certain diseases. Thus Donnè has figured and described a vibrio, under the name of the venereal vibrio; the same observer has likewise noticed in vaginal discharges *infusoria*, which he has named *trichomonades*, and which, as well as the vibrio, are figured in my work "On the Microscopic Anatomy of the Human Body in Health and Disease." Other animal productions have been noticed in the humours of the eye, in the muscular tissue, in the gall-bladder, &c.

The only instance of an *algæ* being found in connexion with the human subject is that recorded by Dr. Arthur Farre: it was observed in a case of vomiting, and has been named *Sarcina ventriculi*. It is now to be observed that the greater part of the living productions noticed in relation with man have had their seat on the surface of the body, in the stomach, intestines, gall-bladder, or in the urinary passages, uterus and vagina; that is, almost invariably in positions accessible to

the air, an observation leading to the conclusion that they found their way into the frame from without. The general immunity of the lungs from parasitic developments, either vegetable or animal, is remarkable.

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131. The *diatomaceæ* are, I believe, furnished with skeletons of siliceous matter; what becomes of them when introduced into the stomach, and is it probable that they could give rise to results injurious to health?—The vitality of the *diatomaceæ* is most probably destroyed when introduced into the system; they pass, however, in an entire state, and when consumed in any quantity, it is quite possible that they might give rise to irritation, in consequence of their unyielding nature and of the elongated and needle-like character of most of the species, the extremities of the frustules frequently being finer and sharper than the points of needles.

132. You find some animalculæ show the presence of decomposing animal or vegetable matter, but I suppose you have not had evidence of persons going from one kind of water to another, and finding variations of health in consequence?—I have no original observations to offer on this point. I would remark, however, that except in times of epidemics we ought not to look for any sudden or violent effects from the use of water impregnated with living or decomposing vegetable and animal matters; these effects, like those of vitiated air, are slow and insidious, but not the less important and the less to be dreaded.

Hector Gavin, M.D., F.R.C.S. Ed., Lecturer on Forensic Medicine,
Charing Cross Hospital, examined.

Have you not paid considerable attention to the sanitary condition of your district?—I am intimately acquainted with the sanitary condition of the surrounding districts.

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And you have also been engaged as Medical Inspector in aid of the General Board of Health?—Yes.

Have you observed the water supply in your neighbourhood?—I have, very particularly.

What are the districts, and by what companies are they supplied?—Hackney, Bethnal-green, and Shoreditch; they are supplied by the New River and East of London Water Companies, and on the intermittent system.

What proportion of the people you visited during the house-to-house visitation were supplied by stand-pipes?—In Hackney about half the houses are supplied by stand-pipes; in Bethnal-green, with very few exceptions, the dwellings of the poor are supplied with water by means of stand-pipes; in Shoreditch a larger number of houses have water laid on, but still the number of dwellings supplied by stand-pipes is very considerable. In a few instances some squares or rows of houses, as Thorold-square, Bethnal-green-road; the Crescent, Hackney-road; the Crescent, Union-street, Kingsland-road, have sunk reservoirs communicating with the main, which by means of a pump supply water constantly to the inhabitants. With these exceptions all poorer and middle-class dwellings in Hackney, Bethnal-green, and Shoreditch are supplied

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as I have mentioned. The poor preserve the water either in 1^o butts—cisterns are almost unknown (I only met with two attached to the dwellings of the poor and middle classes in Bethnal-green, the one was a large covered butt, the other an open wooden cistern containing the remains of cooked fish), or 2^o small tubs, or earthenware jugs, pans, or sometimes in small crockery-ware bowls, and sometimes soup-plates. Water preserved in such tubs or pans is nearly always taken in-doors. Such vessels are never covered. Even where there are small butts, the water is still preserved in-doors in small open vessels; when there are tubs, the tubs are very frequently stowed away below the beds. In one instance a child fell into one of these tubs, which projected from below the bed, and was drowned.

Then it is incident to this plan for having water from stand-sipes that the people keep the water in their rooms?—Yes; even where there are butts, they are so small that the people attempt to increase their store of water by preserving some in open vessels in their rooms; in all other cases it is the nearly invariable practice of the poor to preserve their water for drinking and cooking *in their rooms*.

What is the effect of the retention of water in close atmospheres?—In some places I have found the water used for drinking and cooking almost putrid, even where it had stood for a short time only; in nearly every place, whenever the water has been retained for a day, it has become offensive to the taste. When the water is preserved outside of the house, it is always retained in open vessels; the butt is generally situate close to the privy, sometimes under the same roof; the water is therefore always exposed to the impurities floating in and liable to be deposited from the atmosphere, and always liable to be contaminated by the absorption of foul and malarious air arising from the privies and the back yards saturated with the débris of decomposing matters. When water is taken into the close, heated, and offensive rooms of the poor, it rapidly absorbs the offensive gases, &c., and becomes tainted; and when the water has been preserved some time in butts or tubs outside, exposed to the foetid atmosphere of a privy, it taints still more rapidly. It is almost impossible, on calling for a tumbler of water in the houses of the poor, to find it free from a mawkish taste. As an example of the mode of supply by butts, I may refer to Beckford-row, Bethnal-green. The butt, 21 inches in diameter by 12 inches deep, is under the same shed as the privy. It supplies water to Beckford-row and Alfred-row; the former consists of 16 2-roomed houses, each having a separate family. The latter row is the southern half of Beckford-row; the water supply to the occupants of these 48 rooms consists thus of about as much as would subserve to the wants of one individual. When it is considered that the supply is intermittent and thrice weekly, the deficiency in the storage for water under the intermittent system may be estimated. A particularly objectionable manner of storing water consists in retaining it in small butts or tubs, wholly or half sunk in the ground. This mode prevents the butts or tubs from being cleansed, and the sediment which collects from being removed. Water retained in such receptacles is of a mawkish, earthy taste. This mode of preserving water is common to several of the places called “gardens” in Bethnal-green. It follows, from the general want of external means of storing water, and from the

small size of the existing receptacles, that the poor are compelled to preserve their water in small vessels, and, as a rule, in their own rooms.

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What was the size of the butts?—Ridiculously small; the tubs are generally shallow vessels, which expose the whole surface of the water to the filthy atmosphere, and they are generally placed, as I have observed, close to some privy or dungheap. As an example of the mode of supply by butts, I may refer to the small barrel for the storage of water for the inhabitants of Beckford-row.

Do you concur that if the system of distribution were such that the water might be laid on in each landing-place, already filtered, a great alteration would result in the habits of the people?—I know nothing that would more immediately effect a great change than an ample supply of water. The habits of the people are created by circumstances and by education. Nothing struck me more forcibly than the arduous efforts of the poor in the districts I have mentioned to be cleanly, and the readiness with which, on a supply of water being laid on, they have availed themselves of the means of cleansing it afforded. In the erections of later date in towns and cities, where a constant supply of water has been laid on to each house, this mode of supply in a very short time led to a marked difference between the habits of the people who were, and those who were not, thus supplied with water; and I have observed similar results during the late visitation, when supplies of water were in some instances more liberally accorded. I have found the poor busily engaged, when it was on, in scouring and washing down their foot-paths and yards, and congratulating themselves on the opportunity which this extraordinary supply afforded them of being clean "*for once.*" I have invariably found that where there were larger supplies of water, the people were more cleanly in their persons and dwellings. Under the present system cleanliness, either of person or dwelling, is perfectly impossible. This uncleanness results not only from the impracticability of storing water sufficient for their wants, it arises in numerous instances from the water from the stand-pipes, on each occasion of its "coming on," flooding the yards, courts, paths, &c., and keeping the place constantly miry. Besides the mere uncleanness arising from this mode of supply, the system is most injurious in another way:—When the water is on, a partial flooding takes place, in consequence of the want, or the insufficient state, of the drainage. The water sinks into the ground, renders the houses damp, and the inhabitants diseased; by the partial flooding of the yards, the refuse with which at the present time they are almost invariably covered becomes moistened, and during the process of drying in the sun the moisture readily carries up the destructive products of the decomposition going on. I am satisfied from my own observation that much disease is produced in this way. The quantity of water thus run through the drains by overflow is just sufficient in such places to stir up the putrescent mud in the half-choked drains, without ever effectually cleansing them. By the proposed system of distribution much toil and labour would be saved to the poor, especially in close and lofty dwellings, such as in the cholera districts of Bethnal-green, Shoreditch, Spitalfields, Whitechapel. Where there is much labour entailed on the poor in carrying water up and down stairs, cleanliness is much neglected, and the upper rooms generally show more neglect and uncleanness than the lower. In Whitecross-place, for

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instance, referred to in my Report on Shoreditch, there are five stories to some of the houses, each room containing a family. The deaths from cholera took place in the very top story, which showed much more uncleanness than the lower rooms. In these upper rooms the inhabitants used the water over and over again, until it became very offensive, and "past using." The drinking-water is stated by the visitor to have been "horribly offensive." The poor man, a shoemaker, and his wife, stated a few days before their deaths that they had not tasted a drop of water fit to drink since they had been in that house. Besides the results just referred to, the foulness of the water, acquired by exposure to a close and offensive atmosphere, renders it particularly odious to the poor as a common beverage. The water, often very much loaded with sedimentary matter, and subsequently rendered offensive, becomes unpalatable to the poor, who have no means of filtration; they therefore have recourse to beer, which has become a common beverage of the people of London, as much, if not more, from the impurity of the drinking water supplied to them than from any other cause. I have, in making inquiries among the poor, constantly had this reply,—“We cannot drink the water, Sir, it is so nasty; it makes me ill.” This common observation among the poor is borne out by the evidence of strangers, who generally complain of slight diarrhœa after drinking the London water for a few days. I have every reason to believe, that were a pure and wholesome water supplied to the poor of London, it would be found that in a short time intemperance and beer-drinking would become much less common. This evidence is the result of my inquiries among the poor themselves, continued for several years.

During your experience of the recent epidemic could you trace the effects of using foul water?—The connexion between foul drinking-water and cholera was established by irrefragable evidence. The cases where the connexion was most clear were where the parties had been recently drinking water taken from pumps near to, and contaminated by the matter of cesspools; but wherever the water was contaminated so as to be nauseous, diarrhœa was invariably present, and affected every person in the habit of drinking such water. I am not aware of any valid exceptions to this law. The most aggravated instance of foul water developing cholera was where a thirsty navigator drank of the Hackney-brook (a common sewer), and was almost immediately attacked with cholera, and subsequently speedily died. The cases next most marked were those of the 11 persons, out of 22 in number, whom I have already recorded as having perished in a certain square consisting only of a few houses, where the water was contaminated with cesspool matter. A similar story I have related with reference to the first outbreak of cholera at Fulham. In Hackney I have shown how that, out of 63 inhabitants of one locality who drank of water contaminated with cesspool matter, every one had had, or then had, more or less diarrhœa, and that to avoid its excessive filthiness the whole of the inhabitants of that row were compelled to drink and use for domestic purposes the water which ran down the kennel. These are the more marked instances, but the cases where foul water led to the development of cholera were so numerous, that all the visitors under my superintendence united in their testimony as to the influence of such water in the development of the disease. I have traced in many instances the unsuspected cause of the

development of cholera in the state of the drinking-water. When it is recollected that the water of the poor is nearly always exposed to the noxious gases and agencies which arise from privies, and the slow decomposition of the refuse in their yards, and also from those in their close, offensive, and impure dwellings, it will at once be understood that such water produced much and severe diarrhœa during the period of cholera.

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Is it within your observation that a considerable waste of water results from the present system of distribution?—Yes, a very great waste; for, as a general observation, a small proportion of the water is caught by the receptacles used in the houses of the poor, and of course the rest runs away during the whole period for which the water is let on. I should estimate the general waste among the dwellings where one stand-pipe supplies two or three houses at many thousands per cent. Where one stand-pipe supplies a whole court much less runs to waste; still, in no instance such as these, that I am aware of, can the waste be calculated at less than three-fifths of the supply. It seldom happens that there is any stop-cock to the stand-pipe, and as it is nobody's business to prevent the waste, and as the poor are sure that in a short time the run will cease, they take no heed, and permit the waste-water too often to saturate their yards, and become a source of disease. If the water were on the system of a constant supply, they would be compelled, for their own comfort to check the flow of water.

Robert Bowie, Esq., Surgeon, examined.

1. You are a surgeon I believe?—Yes.

Mr. Bowie.

2. And have attended especially to the consideration of asylums for affording nightly shelter to the houseless poor, to baths, washhouses, and model lodging-houses, and to other appliances for the improvement of the sanitary condition of the labouring population of the metropolis?—I have.

3. You have also acted in aid of the General Board of Health?—Yes.

4. Were you not directed to make special inquiries on the part of the Metropolitan Sanitary Commission as to the supply of water in the city of London? Will you explain in what state you found it?—In general very scanty, and sometimes altogether wanting. The water often thick, muddy, discoloured, putrid, and unfit for drinking or culinary purposes. I would instance as proofs of this statement, out of a host of others, the houses in Fireball-court, Three Pigeon-court, Cock-and-Hoop-court, Seven-Step-alley, Houndsditch; Crown-court, Seething-lane; Barking-churchyard; Rose-lane, Tower-street; Pewterers'-buildings, Cannon-street; Printing-house-square, Coleman-street; Saddler's-place, London-wall; Ivy-lane, Newgate-street; Mac's-place, Greystoke place, Fetter-lane: all in the city, where the inhabitants thus express themselves, that "The time the water was on was too short, the fatigue of carrying it up stairs very oppressive, and much time lost in procuring it." "There was no water laid on." "Water was got where they could, by begging, borrowing, and from the neighbouring pumps." "They have been without water for eight years, and often more in need of it than victuals." "They have been without

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water for nine years." "The water is dipped with pails, and is often very dirty." "The water, instead of being clear and fit to drink, often looks quite yellow." "The water in the cistern is only fit to rinse a pail or cleanse the privy, as every impurity gets into it. It has even been used for drowning kittens. - Two open tubs stand behind the door of the kitchen as water-butts, and have only been cleansed out once in the nine years." "The water (supplied from a pump) is shockingly bad, tasting as if they were drinking something putrified, and often containing live worms more than an inch long, supposed to be from the burying-ground at the back of the house." In addition to this, a gully-hole is in close connexion with the pump by which foul water may find its way into the well. There is an evil of considerable magnitude likely to result from the practice of having public pumps or stand-cocks to supply a neighbourhood with water. It is that, as children and females have to go and wait their turn, they may come in contact with persons of the worst character, hear very bad language, have their sense of delicacy impaired, and at last become regardless of decency.

5. Have you observed any effect which you think was due to the position of cisterns and butts in houses?—Yes, in badly ventilated cellars, for instance, where water was kept near the privy or cesspool, I found that the water had become very unpleasant.

I am of opinion that the common practice of placing water-cisterns immediately above water-closets (unless for the sole use of these closets) is not only injudicious but abominable, seeing that the pipe conveying the water must often be charged with most offensive gases, which in passing through the water in the cistern are likely to communicate a portion of their odour.

In consequence of my attention having been drawn to this point, I caused the valve mentioned in my evidence before the Sanitary Commission to be made fast in the cistern of the Eastern Asylum, instead of allowing the water to flow into the closet, until a separate vessel has been provided. It was the sound of the air rushing into the cistern when the valve was raised that first excited my suspicions.

6. How did you find water in rooms where they were crowded?—Generally very impure and offensive.

7. Then, according to your experience, water, which when procured from its source was good, became bad before it was consumed?—Certainly: I have seen it with a film of dust upon its surface, and smelling shockingly, when it had been kept in the house for some time in pails, tubs, pans, jars, and pitchers;—vessels themselves scarcely ever sufficiently cleansed, owing to the difficulty and labour of procuring a proper supply of water.

8. Have you had experience of a population using soft water?—Yes, in several parts of Scotland.

9. What is its advantage in culinary purposes?—I have frequently heard persons who had been accustomed to use soft water remark that hard water was not so well adapted for making tea or cooking vegetables.

10. Is not the New River supply complained of as hard?—Very often, and with great justice. It curdles soap quite as much as it dissolves it.

11. What is the difference of the water in making tea?—Soft water gives a much stronger extract: where the water is very hard a greater quantity of tea is required. People often think the tea itself is not strong; and I have seen some ladies put a lump of sugar into the tea-pot, and others a little soda, for the sake of extracting the strength of the tea, where the water was hard.

12. If the water were agreeable in quality, and so distributed as to be regularly supplied and easily attainable, do you not think that a large portion of the labouring classes would prefer drinking water to gin or beer?—I am certain of it, for I have often heard persons declare that they were so distressed for water as to be obliged to resort to beer or spirits.

In Merthyr Tydfil, Pen y darran, and Dowlais, in South Wales, the scantiness and badness of the water were again and again assigned to me as the chief causes of the excessive drunkenness so general in these places.

13. Do you believe that if soft water could be procured it would be much better for bathing purposes also?—There cannot be a doubt of it: hard water, as I have already said, curdles soap, and renders it to a certain extent unserviceable. I consider that pure soft water, while it would be more agreeable to the skin, would be more effective without soap than hard water with it.

14. Will you compare the water used in the baths at the east end of London with the Artesian well water at St. Martin's baths?—The following extract from Mr. Lewis Thompson's Report on the water used at Goulston-square will perhaps suffice. "The specific gravity of the water of East London is 1.004. It is turbid, and contains a yellow tinge, even after filtration. When heated highly, atmospheric air and carbonic acid gas are disengaged from it, and, by boiling, a precipitate is produced. An imperial gallon contains the following solid ingredients: Carbonate of lime, 18.55; sulphate of lime, 5.25; muriate of lime, 7.85; organic matter, 4.20; with distinct traces of common salt, sulphate of soda, and oxide of iron. The water is very bad after heavy rains.

15. Do you find that hard water has an effect upon the pipes in which it is conveyed?—It has; at Goulston-square baths the pipes became so encrusted, that sometimes only four or six baths were available for the whole establishment. This was owing, however, in some degree, to the high temperature necessary to force the hot water from the boilers into the baths, and the defective state of parts of the new machinery; for at Glasshouse-yard free baths and washhouse, using the same kind of water, no such accident has ever happened. The water supply to both establishments is from the East London Water Company. I saw a very large pipe at the City Club, Broad-street, completely blocked up with similar incrustations. It had been used for circulating water at a very high temperature for warming the building. The supply was from the New River.

16. The water at the East End is delivered unfiltered, is it not?—Yes; and after rain is very much discoloured, thick, muddy, and contains a good deal of vegetable fibre and other organic matters. The first year of the potato disease I imagined, as did others to whom

Mr. Bowie. I mentioned the circumstance, that the water both from the New River and the East London Works had the peculiar smell belonging to that affection, especially after heavy rains or land-floods.

The following statement was made to me by a respectable individual well acquainted with the locality :—

The water from the Thames passes up the river Lea at the top of spring tides, rises above the level of the reservoirs or tanks of the East London Water-works, at times filling them. The water of the Lea, near Bow, is exceedingly foul. Numerous dye-works, breweries, distilleries, chemical works, foul black marsh ditches, full of everything horrible, and common sewers of large diameter, empty themselves there. There is also at times a supply of highly offensive and deleterious matters carried into it from the chemical and copper works on Bow Common, a place famed for its intolerable stench, and never visited but on business or from necessity.

I have satisfied myself that this is no overdrawn picture, and lament that fellow-beings in this age of civilisation should be so dirty in their tastes and habits as to remain contented with water so contaminated, when, by proper filtration, the evil might be greatly lessened.

At the East End of London, in addition to the impurity of the water, the supply is far too scanty, and in innumerable instances wanting altogether. In corroboration of this I offer a few extracts from evidence in my possession :—

SUN-COURT, EAST SMITHFIELD.—“To supply about a dozen houses the water is on for half an hour daily.” “Sometimes not at all.” “Not half enough for the people in the court.” “The family, seven in number, use 5 or 6 pails daily (10 or 12 gallons) when it can be got.” “If 20 gallons were used it would be better, as there is only one privy in the court, and it is so dirty no one can go into it.” “The water is seldom clear, sometimes very muddy.”

COOPER’S-ROW, EAST SMITHFIELD, contains about eleven houses ; five of which are supplied with water from a stand-cock, and four have no right to water at all. As might have been expected, in the latter houses the occupants are miserably dirty, wretched, loathsome, and generally depraved.

COOPER’S-COURT, BLUE-ANCHOR-YARD, contains fourteen houses, all densely inhabited. In this court cholera prevailed to a most alarming extent. The water is only on for an hour daily. The tap is not an inch, it is only about half an inch, in diameter, being what is termed throttled near its orifice, presenting, therefore, a most deceptive appearance to a superficial or mere outside examiner. Averaging the population of this court to be 3 to each room, as there are 3 rooms in each house, the total will be 246, supplied from a $\frac{1}{2}$ -inch tap, for an hour, or say two hours, daily, not including Sunday, the water running a part of the time so slowly as to take a quarter of an hour to fill a two-gallon pail. But, besides the inmates of these houses, there are numerous applicants from Blue-Anchor-yard, who, like those of Cooper’s-row, have to “beg or borrow.”

All of those whom I saw or conversed with there complained bitterly of the want of water.

I may say, without fear of contradiction, that from Rosemary-lane,

and its continuation eastward, Cable-street, to East Smithfield and Ratcliffe-highway, on the south the supply of water is exceedingly defective, and the water itself very often impure.

17. Does it come within your observation that in a period of epidemics the quality of the water increases the danger of its use if bad?—During the raging of the cholera I met with many cases where it was asserted that the badness of the water was the cause of the attack; and I have no doubt that it greatly tended to increase the liability to disease.

It is well known that cholera raged with frightful and destructive violence in Merthyr Tydfil, Pen y darran, Dowlais, and other mining towns and villages in South Wales; and in all of these places I heard the opinion expressed by many of the population that it was something in the water. The supply was wretchedly defective, and the water very impure. I may also refer to my report on Bermondsey; where, speaking of Jacob's Island, I mention that, "in this island may be seen at any time of the day, women dipping water with pails, attached by ropes to the backs of houses, from a foul fœtid ditch, its banks coated with a compound of mud and filth, and strewn with offal and carrion, the water to be used for every purpose, culinary ones not excepted; although close to the place whence it is drawn, filth and refuse of various kinds are plentifully showered into it, from the wooden conveniences of the wooden houses overhanging its current, or rather slow and sluggish stream; their posts or supporters rotten, decayed, and, in many instances, broken; and so little regard is paid to decency that women may be seen entering and leaving these projecting conveniences, and the filth dropping into the water, by any passer by. I was also informed, that during summer, crowds of boys are to be seen bathing in the putrid ditches, where they must come in contact with abominations highly injurious.

18. Was much of this supply obtained from the ditches in the neighbourhood?—Yes; some water was obtained from the Vauxhall Company's supply, but it was very limited: most of the houses were supplied from these ditches and mill-streams.

19. You say this bad water was from the ditches, not from the Company's supply?—Yes.

20. It is stated in evidence, both by the Engineer of the Vauxhall Company, and corroborated by their evidence, that about 190 or 200 gallons of water are pumped into this district per diem for each house which has a supply, and that about two-thirds or three-fourths of that quantity overflow from the butts and are wasted, and that in this particular district there is an amount of annual waste of water which equals, if it do not exceed, the whole quantity of annual rainfall in that district?—I have no doubt of it.

21. What is the average size of butts in that district?—About 60 gallons on an average.

22. Then you do not believe that poor persons use 20 gallons a-day?—Certainly not; they do not use 6 gallons oftentimes for a whole family, and frequently much less. If, however, they had it plentifully supplied them, without the trouble of carrying it up stairs, they would certainly use much more. Now they are so careful of the water, that it is often used first to wash one kind of clothes, afterwards

Mr. Bowie. another ; and even then used a third time for some other purpose, until the effluvia become most offensive and sickening, communicating an odour to the clothes and persons of the inhabitants, rendering them exceedingly disagreeable.

23. Is there not here a great waste of human labour, considering that it was stated by the secretary to one of the London companies, in evidence before the Health of Towns Commission, that 80,000 gallons of water may be lifted by a Cornish engine 100 feet high at the cost of one shilling?—Yes ; and it is likely to deteriorate materially the health of the population. As water might at very little expense be laid on in every landing-place, it ought to be done ; for in poor neighbourhoods distinct families generally live on every floor. Now they often have to go down to the very cellar, or to a little back yard close to the privy, if they are fortunate enough to have the water supplied on the premises.

24. With reference to Jacob's Island and the district in Bermondsey which was ravaged by cholera, it is stated in evidence that, within 4 months from the time when the works might be commenced, all the cesspools might be abolished ; that soil-pan apparatus might be laid down ; that a system of complete house-drainage might be established ; that permeable drainage might be laid down, which would carry away all the damp : and that all this might be done at a permanent charge, exclusive of the cost of water, of not exceeding 2*d.* per week per house. Supposing that were practicable and could be done in 6 months, what is your opinion with regard to any impending epidemic?—It would have a most happy effect, and produce a great result towards diminishing the violence of such an epidemic, or preventing its visit altogether. Wherever I have visited I have found that the attacks of epidemics are most infrequent where the most attention is paid to drainage, and where drainage has been most neglected the attacks are most malignant. The greatest blessings London could receive would be a good supply of water, proper sewerage, the removal of cesspools, and better ventilated dwellings.

25. Since your last examination before the Commissioners, have you considered the possibility of pointing out the track of the occurrence of cholera?—I think I could map out the track it would follow if the cholera should revisit us, as I fully believe it will ; and Bermondsey would certainly be included in that map, together with Goulston-street, Church-lane, Bethnal-green, Rosemary-lane, Spitalfields, Wapping, Lambeth, and along the banks of the Thames, even in the City.

26. From what you know of the tenants of such property do you concur in the opinion that new charges or large demands for outlay, either upon the owner or occupier, would be nugatory?—Wholly so.

27. And you concur in the opinion that the object desired would be maintained by distributive charges, such as a charge of 2*d.* per week per house?—I think it would.

28. You therefore are of opinion that all means of economy, by a combination of work and a distribution of charges, will be essential to the prevention of such disease?—Certainly so.

29. Is it true that captains of vessels take out Thames water in preference to all other waters?—A few years ago such was almost the universal practice, but of late the belief in its superiority is considerably shaken,

some giving the preference to the Shaws water, Greenock ; others to that from St. Helena, and others again believing that the water of the Ganges is quite as good as that of the Thames.

Those who still prefer the Thames water say that, although it at first becomes very bad, after all the bad gases are thrown off it becomes as it were aërated by the marine atmosphere and again becomes very clear. This it is not so likely to do if kept in close towns and surrounded with impurities.

30. Will you ascertain from any captains why it is they prefer the Thames water to any other, and in what they think its particular advantages consist compared with the water of the Tagus or other river-water?—I shall endeavour to do so. Meantime I may mention that I have heard them say who prefer it that “it will keep good in climates where none else will keep.”

31. Do the ships of the Royal Navy take their water from the Thames ? —Water is supplied to the shipping in the Thames chiefly from the river itself. For large ships going long voyages or carrying passengers, it is generally filtered, or professed to be so, and sent on board in barges ;* but for the smaller-class vessels no such precaution is taken ; and while they are lying in the river it is dipped with pails and used for every purpose. Indeed, alongside the river, houses have no other water. This is surely a weighty reason for endeavouring to keep the river from pollution. The amount of disease occurring on board the shipping, and in the houses in the vicinity of the Thames, affords ample proof of the necessity of sanitary improvement. In an impure atmosphere good health is not to be expected : on the Thames, or in its vicinity, as it runs through the metropolis, a pure atmosphere is not to be found. Having on a former occasion expressed my opinion of the danger of making the river a common sewer, I shall merely add the following particulars concerning the use of Thames water in the Tower : “Beginning at the Seven-gun Battery, at the eastern gate, the water was very thick and discoloured, and actually alive. The water from a pump at the Spur Barrack stank so much that a horse or pig would scarcely have drunk it.” “All the tanks, with the exception of one, were in a very bad state, and even in that one, which had a charcoal filter, animalculæ were perceptible.” “Generally after having been pumped in two days it resembled milk and water, and could not be seen through.” In this state however it was used for ordinary purposes.

“The medical officer of the garrison recommended that spring-water from the Tower ditch should be used for drinking and culinary purposes, but the aged and the feeble would not take that trouble.”

“The water supplied to the Tower was pumped from the Thames at a certain point within 200 yards of a sewer, the contents of which were all the blood and refuse from the butchers’ shops and slaughter-houses in Whitechapel.” “The soldiers and all the inhabitants of the Tower complained of the water, and attributed a great deal of the disease to the bad water.” “A regiment that came from Chichester had eighteen on the sick-list three days after their arrival.” The sickness

* It is not very unusual for a barge to go outside of the dock after having discharged the whole or a great portion of her load of water, and, by the withdrawal of a plug or two, soon re-enter, reladen ; the water having been thus stealthily admitted without any filtration whatever.

Mr. Bowie." on that occasion was likewise attributed to the impurity of the water.

"The cases of cholera in the Tower were considered more malignant and rapid than in the worst parts of the Metropolitan Eastern District."

In compliance with the instructions contained in the 30th question, I have obtained the opinions of several sea-captains concerning the properties of waters of various rivers or water supplies used for long voyages.

Captain Coubrough, who has made many voyages to India, the West Indies, and other distant places, says "that the Thames water is generally considered the best for taking to sea, because, although it soon gets bad, it speedily recovers, even when kept in casks, especially by taking the bungs out and allowing the gases to escape. Putting it into iron tanks is another means used for sweetening it. In one of his ships there was an open pipe passed from the tank through the deck, allowing the escape of gas and the admission of air, by which the water was always kept sweet. The Shaws water, Greenock, keeps longer than that of the Thames; indeed, with proper care there is very little risk of its becoming putrid at all. A handful of lime was put into each cask at the time of filling, and the water kept good all the way to Port Phillip, a 5 months' voyage. For his own part, he does not think the Thames water superior to that of many other rivers."

Captain Potter gave the same account of the water of the Thames, Shaws, and Ganges, and thinks the St. Helena water of still greater purity.

Both Captains Coubrough and Potter stated that rain-water caught at sea from the ship's decks, sails, or awnings, however clean they may be, if put into a cask and bunged up, will become putrid in a few days, when, if the bung be withdrawn, the water will be full of vermin and flies, and the latter will fly out of the bunghole in myriads. This water, if put into iron tanks, will soon get sweet again. In warm weather, if there be any damp in any part of the ship, she will soon fill with flies and mosquitoes even at sea. A damp cabin in a southern latitude is always full of them; in a dry one they are seldom seen. Captain Potter mentioned that scurvy is much more common in Bombay than Calcutta ships, although they are equally well found, and the voyage shorter to St. Helena. He has even known lady passengers so affected. This is no doubt owing to the badness of the water, it being all brackish when taken on board at Bombay.

An eminent shipowner and merchant told me that the Thames water was considered the best for taking to sea, as it soon purified itself; that when it became putrid it was very bad, and that the gas escaping from the bunghole could be ignited with a candle. He also stated that the process of putrefying and becoming sweet again, took place several times during the voyage. Since iron tanks were introduced he hears no complaints of the water, which is said always to be very good.

Captains Coubrough and Potter said that the preceding statement is quite correct as to what takes place with respect to the repeated changes in the water, and as to the gas being inflammable.

Captain Brown, stated that the Thames water, or indeed any water

generally taken to sea, may be sweetened when becoming putrid by exposing it to the air for a day or two. Mr. Bowie.

Captain Tasker, of the "Prince George," states that the description given by the preceding witnesses is quite correct, and adds, the water from the St. Lawrence at Montreal and Quebec so exactly resembles that of the Thames, that the difference could not be ascertained; and that it, like the Thames, receives the impurities of the towns.

Captain Hartley, of the "John Ormrod," says, "The chief part of the water supplied to the shipping at Bombay is rain-water. It is previously collected in stone tanks lined with Roman cement. These tanks are called buffalo tanks. The water in them is brackish, of a milky white colour, and covered with a green slime like what is seen on ditches in this country. The use of this water gives rise to and increases diarrhœa and dysentery. Besides the buffalo tanks there are two large reservoirs or tanks capable of containing 120,000 gallons, in which water is stored in case of drought. At Cronstadt the water is dipped out of the river in the same way as from the Thames. All the filth from the town runs into the river. The water is not half so good as that of the Thames. It is brackish, and causes or aggravates diarrhœa and dysentery. Has suffered severely himself from it both in Bombay and Cronstadt. St. Helena water and that of Ascension the finest got anywhere, although that from the Cape of Good Hope is nearly as good. Beautiful water is also had in New Holland and Hobart Town. At Whampoa the water, as taken out of the river, is very foul, worse than that of the Ganges. Last voyage from London the water was pumped direct out of the Thames."

Captain Skinner, a retired shipmaster, gives the preference to Thames water, because although it may sometimes be bad it soon gets right again. He says the water at Riga is very bad. It is of a reddish colour, supposed to be from the hemp, fibres of which are abundant in it. It is the general belief, that all those who use the Riga water, soon fall into diarrhœa, dysentery, or ague. Suffered very severely himself from diarrhœa, ending in dysentery, and has no doubt it was owing to the water. That the attack was a severe one, I can testify, having had him as a patient here afterwards, and almost despaired of his recovery.

ROBERT BOWIE.

All the captains I have spoken to on the subject are unanimous in their opinion, that exposing putrid water to the air, renders it sweet. If this be the case, and there seems no doubt of it, a foul river must be a dangerous neighbour.

LETTER from JOHN LIDDLE, Esq.

DEAR SIR,

4, *Alie Place*, 5th January, 1850.

THERE are several courts in the Whitechapel union which are without a supply of water. In all there is a deficient supply. The poor inhabitants are for the most part supplied with water from a stand-tap, the water from which flows daily for a short time (from one hour to three hours). Some of the houses where the poor reside Mr. Liddle

Mr. Liddle. are three stories high; and as the water only flows for a limited time in the court, the lodgers in the attics of these high houses must either go without water entirely, or obtain a limited supply, with a great deal of labour and loss of time.

In Johnson's charge, where more cases of illness have occurred than in any other locality in Whitechapel, the only supply of water for the inhabitants is a pump, the water from which is said to be unfit to drink, and the poor people are obliged to obtain their supply from a neighbouring court, and they have great difficulty in procuring it, the inhabitants objecting to let them have any.

In Cartwright-street the inhabitants are supplied from a well, the water from which is pumped into a tank, and pipes are connected with it, from which the butts in the houses in the neighbourhood are supplied. But the machinery is sometimes out of repair, and the inhabitants have then to obtain water elsewhere. In some instances the water-butt is adjacent to the privy.

In Hebrew-place and Love-court, Middlesex-street, the tenants of one of the landlords are without any supply of water except that which they may obtain from a pump. Here these poor people say that the water from the pump is so bad that they cannot use it, and they are obliged to beg it from their neighbours. In this case the landlord had a dispute with the Water Company, in consequence of their giving him notice to raise the water-rate during the rebuilding of some of the houses; alleging as the reason, that the quantity of water which was required for the mortar for the building of houses was much more than was needful for the occupants. The landlord resisted their demand, and the water was cut off.

In the month of August last a complaint was made by a party residing in the eastern extremity of Whitechapel, to the trustees, of the bad state of the water which was delivered into their premises. A sample of the water was shown to the trustees; it was most foul and foetid. A committee of the trustees was appointed to make inquiries into the case, and found it as described. The Water Company was written to, and new pipes were laid down. Whether the company made any deduction from their annual charge I do not know.

The water which is delivered into my own house is unfit to drink, unless previously filtered. It is usually turbid. All complaints are of course useless. The only reply would be to a complaint, "If you don't like it we will cut it off."

Very truly yours,
(Signed) JOHN LIDDLE.

P.S.—The trustees recently passed a resolution complaining of the bad quality, deficient quantity, and extravagant charge for watering the parish.

Alexander Bain, Esq.

Assistant Secretary, General Board of Health.

John Challice, Esq., Surgeon, examined.

You are, I believe, a surgeon?—Yes.

Mr. Challice.

Where do you reside?—In the Grange-road, Bermondsey; I am also chairman of the Bermondsey Board of Guardians, and have practised in Bermondsey for the last seven years, and largely among all classes.

You were of course called into active service during the cholera?—Yes, very much so.

Had you at the time any reason to believe that the extensive severity of the visitations of cholera in the district was influenced in any immediate degree by the supplies of water?—Yes.

Would you describe to the Commissioners the facts which led you to that conclusion?—The first fatal case of cholera that I met with was that of a master of a vessel at Gravesend. He was a fine man in the prime life, and in perfect health when he left London. He was going to the Baltic; he drank rather largely overnight parting with his owners and others, and he got up in the morning and drank heartily from one of the water-casks, which had just been filled with Thames water; he was soon after attacked with purging and vomiting. I went down post, and found him just dead. I asked particulars, and I found that the death was so sudden, that it almost appeared as if he had taken poison in the water; subsequently it was from facts that came almost hourly under notice that I formed the opinion of the direct consequences of taking impure water in producing a disordered state of the bowels, and those who had such a state of the bowels were pre-eminently in a condition to become victims to the disease.

Of course during an epidemic, when the general health is depressed, causes which have generally no perceptible effect materially affect population. Did you perceive these causes in action at the time you mention peculiarly?—Yes, undoubtedly; there was the case of a man who lived in the Coburg-road, in Camberwell parish, in a semi-detached house, in a healthy situation, and with a garden behind the premises; his wife had noticed that the water supplied to them was exceedingly bad, and, having been informed that it was likely to affect the health of her family, she invariably boiled and filtered it: all kept in perfect health except the father, who objected to drink this water, from its being flat and unaërated; he would still drink it as it came from the water-butt, and the consequence was that he was attacked with cholera-diarrhœa; he afterwards drank no more of it, and got well.

Then you consider this to be a fair example of the effects of using such water at such a time?—Yes; and I found that where deep-spring water alone was used, where such water was free from the effect of percolation from the drainage, persons escaped the cholera altogether.

Do you know what company supplied this water?—Either the Lambeth or Vauxhall.

I believe the one company filters the water, while the other does not, except by its subsidence?—I believe so; the water I speak of as it came in was filled with animalculæ before it was let into the tank.

Are not the water-butts and other receptacles often placed near the privies?—Yes, very generally.

Mr. Challice.

Would not that alone be likely to contaminate water that might be pure at its source?—Yes, certainly; but here it came in with animalculæ in it.

But you think that the plan of receiving it in butts is bad?—Yes; the purest water under such circumstances would soon become impure, and a source of disease.

Have you observed the state of these water-butts?—Yes; very frequently.

Will you describe their appearance?—Generally speaking the wood becomes decomposed and covered with fungi; and, indeed, I can best describe their condition by terming them filthy. The poor people will not cleanse them; and if you look to their cooking utensils you will likewise see a quantity of dirt deposited.

Do you think that the deep-spring waters are free from animal impregnations?—I do; and, if used, would undoubtedly very materially diminish the extent of mortality: indeed, I entertain a very strong conviction that the general use of deep-spring water for human consumption would be of the greatest public benefit. During the prevalence of cholera, I repeat, in my own practice and experience it was the most powerful preservative against the epidemic.

Do you not think there would be this further effect from the supply of a purer water, that it would encourage a more extensive habit of drinking it?—Yes; the stomach is nauseated by bad water, and, being compelled to take a certain quantity of fluid daily, if the water does not agree with people they must take some other drink, such as beer, &c.

Does not that form the excuse with many of the labouring classes?—They could not do without other stimulants, if the water supplied in the neighbourhood is bad as well as the state of their dwellings.

Would you under such circumstances actually advise them to take alcoholic stimuli?—Undoubtedly I would.

Has the quality of the water supplied been at all improved?—I believe it has been much improved in appearance within the last two years. I think this is owing to an improved system of filtration.

Will you describe the way it came in before such improvement?—I have seen it come in looking nearly green, and smelling very bad; before I lived at Bermondsey I resided at this end of London. A young gentleman resided with me as pupil: he was a water-drinker, and had become so ill immediately after drinking the Thames water, that he was obliged to leave and go into the country. Afterwards he came back; but again became ill when he began again to take the same water, and he has always since been obliged to take a little brandy in the water, though he disliked it very much.

Then it is desirable, and indeed important, that the water supply should not only be clear and well aërated, but should also be what the French call "*appétissante*?"—Yes, certainly.

Charles Martin, Esq., Surgeon, examined.

Mr. Martin.

1. You are, I believe, a surgeon, residing in Bermondsey?—Yes, I am, and surgeon to the St. James's district.

2. Is there not within that district a place called Jacob's Island?—

Yes, but according to the new ecclesiastical arrangements, it is not in St. James's parish. Mr. Martin.

3. Was not that district very severely visited by cholera?—Very severely.

4. Can you give any idea of how many deaths occurred in that neighbourhood?—Some idea of the severity of the attack may be formed, when I state, that within the space of a few yards, nine persons lay dead at one period.

5. In consequence of your memorials to the Sewers Commission and to the Board of Health, did you obtain assistance for that district?—Yes, we did in July last.

6. Will you state what observations you made, with respect to the supply of water therein, and what effect the defective supply of water had upon the cholera?—I think in the greater number of houses there was no water to drink but that from the tidal ditches, until about July. At that time a great supply of water was laid on. It had been getting worse for years past; the water in the ditches becoming in some parts absolutely putrid, green, thick, and slimy. I know some clusters of houses where they had only such water to drink, and I know that out of five of those houses the inmates of four were affected with cholera. In all the early cases of cholera, the parties were found to have been supplied with water from these ditches. One case was that of a man from Maidstone, who stayed at a public-house in Mill-street for the night, on his way to Liverpool to emigrate; he arrived on the Saturday, and on Monday was attacked with cholera; in that house no water was laid on; great numbers of the houses in the neighbourhood are still not supplied with water.

7. Can you state whether other places in a similar position with respect to filth, but where they had a better supply of water, were so virulently attacked by cholera?—In the road they had a good quantity of water, but it was bad in quality. There is a nest of houses in that road, the road is 50 yards wide, and the inhabitants of all these houses had cholera one after the other. Yet all were supplied with water by the Water Company, and I cannot account for the result. Similar effects were seen in 1832 in the same street.

8. But may you be understood to state that the greatest intensity of cholera was found where the water was most impure?—Yes, most certainly.

9. Was the water supplied by the Company Thames water?—Yes, it was brought from Battersea.

10. Was it filtered water?—It cannot well be so, as I yesterday saw some of the water in West-street, which was thick and offensive, even at this time of year.

11. What is the character of the water generally given, such as is provided for drinking purposes?—It is sometimes very bad; it cannot be depended on. It cannot be filtered, for I have had brought to me fresh-water shrimps and even leeches which have been taken from it.

12. Is the water, to your knowledge, sometimes in such a condition as to discourage the use of water by the labouring classes?—I know that in West-street, only yesterday morning, one of the lodgers would not take his breakfast, because the water was so bad, that he could not drink it.

13. What have you heard with respect to the quality of the water?—

Mr. Martin. — It is very hard ; and I yesterday was told that linen washed in it had a yellow appearance, and they could not indeed wash well with it.

14. Where are the butts and tanks usually placed?—In the smaller houses they are usually very near the privies.

15. It is needless, then, to ask you, whether the water gets fresh pollution from such proximity?—It cannot fail to do so.

16. Has the drainage in the neighbourhood been at all improved?—In some of the streets it has been partially improved since July last ; but still the smells in some places are very offensive.

17. Are there any soil-pans adopted?—Yes, in some places ; but there is no supply of water for them, and they are still very defective.

18. It has been reported to the Board that at the Cloisters, Westminster, new drainage has been laid down, and that since then no offensive smells have been experienced, and that no refuse remains, that moreover there has been a distinguished improvement in the general tone of the health of the people residing in the neighbourhood : have you reason to believe that such was the natural result of such improvement?—I should quite believe that to be the case.

19. Suppose like improvements were to be carried out in Bermondsey and Jacob's Island, consisting of a good water supply, the abolition of cesspools, together with the application of house drainage, and a drainage of the foundation of the houses, with what difference of apprehension would you regard the approach of epidemic cholera or other epidemics?—Such improvements must tend to diminish the severity of the disease, whenever it may attack us.

20. From your experience of the cholera in 1832 and 1833, do you anticipate a recurrence of that epidemic in one form or another?—Judging from the past, most probably we shall have a return of the disease this year.

21. Have not epidemics been very severe in your district?—Yes.

22. Have you seen the table in the Registrar-General's Report, prepared by Mr. Edwards?—Yes.

23. Would you take that fairly to represent the respective liabilities to the disease?—Yes ; I may mention one case in which the sewers water inundated a house during the summer and autumn, and the whole family have since been attacked with measles. And nearly all the inhabitants of this locality have since suffered from disease.

24. Then the representations contained in your memorials, urging the necessity of improvements being adopted in that neighbourhood are still in force?—Yes, for though much has been done, much more still remains to be done.

CHEMICAL.

Dr. Lyon Playfair examined.

1. Are you not chemist to the Museum of Practical Geology in the department of Her Majesty's Woods and Forests?—I am.

2. You have been engaged in analysing specimens of river, spring, and surface waters from different parts of the country?—Very extensively, and I have examined waters from most of the larger towns in the kingdom.

3. Have you been called on to analyse the Thames water?—I have

examined the Thames water as high as Henley, and also that delivered by the Chelsea and by the Lambeth Waterworks Companies.

Dr. Lyon
Playfair.

4. Will you state the general characteristics of the Thames water you have examined as to its hardness?—I have found the average hardness of the Thames water, from a mean of about 40 observations, to be between 13 and 14 degrees of hardness. I never found it above 16, and I have seen it as low as 11. It has been stated to average 16, but I have never found so high an average, although occasionally it may be so high. In two or three instances I have found it as low as 11, but this was due to accidental floods.

5. Have you analysed the water of the river Colne?—I have examined various streams at Watford, and I think the Colne among them. The Thames has some 17 or 20 tributary streams. They cannot be soft when the main stream is hard. I examined the degrees of hardness of the water at Henley every day for three weeks, and did not find any very great variation. One day the water was 16 degrees, but it generally ranged from 13 to 14.

6. Then you think it probable that, as other chemists state, it may reach 16?—I think that it does so only occasionally. I would not take the average of the Thames water, as delivered in London, to be more than 13, varying from 11 to 15.

7. It has been stated that the Thames water is likely to be affected by the sewage, and that about London Bridge is softer than higher up?—I should think it would become so by the mixture of sewage water. In fact analysis shows the presence of a much larger quantity of organic matter at London Bridge than higher up the stream.

8. You have probably seen other analyses by other chemists. Is there a general correspondence in them with regard to Thames water?—There is very little essential variation more than arises from waters being taken at different times and places, and I here hand in a table of these analyses.

Locality of the Water.	Sulphate of Potash.	Sulphate of Soda.	Chloride of Sodium.	Chloride of Potassium.	Chloride of Magnesium.	Carbonate of Magnesia.	Chloride of Calcium.	Carbonate of Lime.	Sulphate of Lime.	Silica.	Organic Matter.	Authority.
Henley . . .	..	..	2.72	0.70	..	1.23	..	10.42	3.72	0.16	3.55	Playfair.
Twickenham.	0.67	2.00	..	..	..	1.02	1.75	12.76	0.45	0.27	3.48	Clark.
Brentford .	..	..	3.40	..	..	..	..	16.00	..	..	..	R. Phillips.
Barnes . . .	..	..	1.70	..	..	..	..	16.90	..	..	..	..
Putney . . .	..	..	1.31	0.42	..	0.65	..	10.76	1.98	0.73	2.10	J. A. Phillips.
Chelsea . . .	..	..	2.94	0.82	..	1.60	..	10.80	3.04	Trace.	4.25	Playfair.
London Bridge	0.27	3.10	2.37	..	0.08	..	6.97	8.12	..	..	6.99	Ashley.

9. There were some very old analyses, were there not, about the time of Dr. Bostock? has the analysis of water improved?—Yes; because many of the ingredients were not then thought of importance and are now included. In the previous table there are apparent discrepancies, because chemists view matters differently; thus Mr. Clark and Mr. Ashley unite their soda with sulphuric acid, while I prefer to view it as common salt, and the latter acid as combined with lime in the form of gypsum; these are only theoretical differences.

10. Are there not differences in waters appreciable to the senses, and

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yet not appreciable by analysis?—Yes, certainly; I think the organic gaseous impurities in water have not yet been sufficiently examined by chemists.

11. Will not the sanitary effect of the difference of organic matter in water be very great?—I think very much more so than the effect of the mineral ingredients of the water. When waters contain sulphates, as they usually do, the organic matter acting upon them produces sulphuretted hydrogen, a putrid and noxious gas. The organic matter itself also enters into putridity, and innumerable instances of dysentery and diarrhœa have been traced to this vitiation of water. In the recent visitation of cholera, there was abundant evidence that numerous attacks were the consequences of the use of water containing organic matter in a state of decay.

12. Have you had any improvement in the analysis of organic matter in water?—A process has lately been described by Dr. Foschammer, which enables the amount of organic matter to be very readily determined.

13. Suppose you take the case of a susceptible child living on the side of a high hill, who was removed, without any alteration of diet, into a close atmosphere, would there not be found a great difference in its state of health?—Certainly. In this case the vitiated atmosphere charged with organic impurities exhibits a marked prejudicial effect, although there would be no very decided quantity of such ingredients detectable by chemical analysis. In fact, chemistry has not reached sufficiently far to isolate or examine them. We know they are present, because oil of vitriol is blackened by carbonaceous matter, when such air is drawn through it, but beyond the mere fact of its presence we know nothing.

14. Then that which has not yet by analysis been found by chemists will yet govern the quality of the air or of water?—So strong is my impression on this point, that in the midst of the cholera I urged it on the Board to warn the public against keeping water in the house, which though at first entirely pure, would, if kept in cisterns, absorb the vitiated air, and this would find its way, in a very active form, into the system of those who drank the water. In consequence of that recommendation the public were recommended to use boiled water, but that should be used at once, as it is more absorptive than water unboiled. The Chinese are well aware of the effect produced by boiling water containing organic impurities. They are accustomed to use boiled water for the purposes of drinking. A temperature of 212 degrees, that being the boiling point, is sufficient to destroy decay, so that boiled water loses the injurious influences due to the decaying matter which may be present.

15. Then the absorption of the air by water kept in cisterns or close rooms would be very considerable, and the taste of the water would be very likely to be altered?—Yes.

16. Have you any doubt that water exposed to an impure and noxious atmosphere is capable of absorbing noxious and impure matters, and thus proving injurious to the health?—I have no doubt of it; in fact, there is too ample experience in proof of it.

17. What sort of precautions did you recommend at the time of the cholera with respect to water?—I thought the most effective means of

avoiding injurious results would be to boil the water, if it were immediately used on cooling; it should be allowed to cool in a close vessel, because boiled water is more absorptive of all gaseous malaria than unboiled water. It is also advisable, though it does not remove danger to the full extent, to filter the water through charcoal, which removes a large proportion of the organic impurities.

18. Of course at that time, knowing the effect of this absorption, you were alarmed at it?—I was, and I may mention one example of how water absorbs gaseous impurities. One of my assistants was making experiments with an oil, which had the smell of the concentrated urine of a male cat. The smell was insufferably offensive, and was so readily absorbed that it was impossible to drink the water placed in the room, and our clothes, especially the hair, were saturated with the smell, which did not disappear for several days. Every vessel containing a liquid in the room soon became contaminated with this horrible smell.

19. Then it is a great point that the delivery of water should be so managed as to avoid all such absorption?—Yes, certainly it should be so kept as to be always pure, cool, and palatable.

20. What rank would you assign to the Thames water taken as a river water?—The average hardness of water supplied to the various large towns of England is probably not less than 7 or 8 degrees. Accordingly the Thames water would be about 8 degrees above that average.

21. Have you found reason to modify your opinions as to the domestic value of soft water?—I speak with the force of increased experience when I say that I formerly greatly underrated the advantages of soft water. I need not allude to the importance of soft water for washing further than to say 30 ozs. of soap are consumed by every 100 gallons of Thames water before it forms a lather fitted for detergent purposes. The importance of soft water in cooking is less obvious, but no less ascertained to exercise an important influence on the culinary art. With regard to health, accurate observations have not yet been made, especially with reference to the human subjects, but, on animals, the effect of hard water is very apparent. Horses have an instinctive love for soft water, and refuse hard water if they can possibly get the former. Hard water produces a rough and staring coat on horses and renders them liable to gripes. Pigeons also refuse hard water if they obtain access to soft. Cleghorn states, that hard water in Minorca causes diseases in the system of certain animals, especially of sheep. So much are race-horses influenced by the quality of the water that it is not unfrequent to carry a supply of soft water to the locality in which the race is to take place, lest there being only hard water the horses should lose condition. Mr. Youatt, in his book called "*The Horse*," in remarking upon the desirableness of soft water for the horse, says, "Instinct or experience has made the horse himself conscious of this, for he will never drink hard water if he has access to soft; he will leave the most transparent water of the well for a river, although the water may be turbid, and even for the muddiest pool." And again, in another place, he says, "Hard water drawn fresh from the well will assuredly make the coat of a horse unaccustomed to it stare, and will not unfrequently gripe or further injure it."

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22. On the whole, do you think that there are portions of the Thames from which the domestic supply of water ought not to be taken?—I think it unsafe to take it from below where the sewers enter into the river; but higher up the quantity of organic matter at present in Thames water is very inconsiderable.

23. Will you give a statement of the relative quantities of organic matter therein?—The amount of organic matter found in the water of the Thames is described in the table which I have already given.

24. Have you analyzed any artesian-well waters?—Yes, the water at Trafalgar-square, and since then, various deep well waters in London have been examined.

The following table gives the composition of three Artesian-well waters in London:—

	Well at Combe and Delatfield (Graham).	Well at Trafalgar-square (Abel and Rowney).	Well at Royal Mint (Brande).
Carbonate of Lime	6.18	3.25	3.50
Phosphate of Lime	0.19	0.03	..
Perphosphate of Iron	0.24	..	..
Carbonate of Magnesia	1.08	2.25	1.50
Sulphate of Potash	..	13.67	..
Sulphate of Soda	24.25	8.75	13.14
Sulphate of Sodium	12.74	20.06	10.53
Phosphate of Soda	..	0.29	..
Carbonate of Soda	11.68	18.49	8.63
Silica	0.44	0.97	0.50
Organic Matter	..	0.90	Traces.
	56.80	68.66	37.80

25. What are the general characteristics of artesian-well waters?—They are generally of five or six degrees of hardness; they also contain a large proportion of alkaline salts and common salt, but comparatively little earthy or calcareous matter. On an average not more than three or four grains of carbonate of lime, and two of magnesia are present in a gallon. Boiling deprives them altogether of their earthy salts, and renders them quite soft. Hence they are of much value for washing, for baths, &c.

26. Are there other qualities that make artesian-well waters of greater value than Thames water for drinking?—I do not think that they are objectionable for drinking purposes, though they contain a large quantity of alkaline salts. These act on the kidneys, but perhaps not notably in such small doses. The Trafalgar-square water has been lately used in all Government offices. The artesian-well waters are not always free from organic matter, but when they are very deep the quantity present is generally insignificant.

27. Do you concur in the general statement of the limited quantity of artesian-well water available for water supply to the metropolis?—Some of the manufacturers and brewers in the neighbourhood of London arrange to take the water required by them only on certain days, because the supply is so limited that the demand would exhaust it, and

mutual injury must result. At Watford, 24 miles from London, the water in the wells is higher on Mondays than on other days. The brewers, and other large consumers of water, do not of course pump any on Sundays; and it is thus shown that the effect of the London demand extends as far as Watford, *a fortiori* it is much more exhausting in the immediate neighbourhood. Besides, Mr. Clutterbuck has shown, by numerous observations, that the water line of the London Chalk Basin has become permanently depressed by the increased demand upon it.

28. But without depending on artesian wells for the chief supply of London, might they not serve as a contribution for baths, &c.?—Yes, but too great a supply for these purposes might act injuriously on many manufacturers where they depend, as in the case of brewers, on the softness of the water. Although these might be supplied from elsewhere, still this would not be sufficient, as all their experience has been derived from the behaviour of a particular water; and if they were deprived of it, their success as manufacturers might be materially impaired.

29. Beyond the advantages you have stated to result from soft water, can you specify others from its use, for tea, for instance?—It is there of great importance; in fact tea cannot properly be made with the hard water, unless three or four times the quantity of tea were taken that would be required to make equally strong tea with soft water. The injurious effect of hard water is found not only in tea, but also in cooking, where soft water is of great importance.

30. As to artesian-well water, do its saline matters lower its value?—Not to a great extent, because when boiled it becomes soft water. Carbonate of soda being present, on ebullition all earthy matter is taken from the water, and it becomes soft.

31. Supposing an equal supply of artesian-well water were obtainable, would it be of great value?—No doubt, if it were in sufficient quantity; but it is not well calculated to supply cisterns on account of its phosphates, which promote the growth of vegetation. In Trafalgar-square the vegetation grows so that it would soon block up the entrance to the pipes if it were not removed. I was applied to by Government to give an opinion as to the propriety of supplying the Serpentine with that water, and I cautioned it as to an evil which would be found if it were used. This consisted in its disposition to encourage the growth of vegetation, which would give to the public the idea of putridity, and thus create a prejudice against the water.

32. But that vegetation would of course decompose?—Certainly; and acting on the sulphates present in the water, would produce sulphuretted hydrogen.

33. What is the difference in the proportions of organic matter in water, taken at one extreme of the Thames and the other?—I found as much as six or eight grains of organic matter per gallon down about London Bridge; and at Chelsea I found as much as four grains of organic matter, and about three at Henley.

34. Then you generally found the quantity increased as you approach London Bridge?—Generally.

35. Did you take the Chelsea water at any particular state of the tide?—I had it as it was flowing from the pipe into the cistern for the laboratory in Duke-street, Westminster.

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36. You stated that the Chelsea water is filtered?—It is.

37. What proportion would the degree of organic matter in that filtered water have to the general amount of organic matter in the usual London supplies of water?—On an average, it would be decidedly lower.

38. How is it at Henley?—About three grains per gallon; it is not what may be called a large average, still it is a notable quantity.

39. With regard to surface-waters, have you examined the water with which the print-works in Manchester and Liverpool are supplied?—Yes; and also the supplies to most of the large towns in Scotland.

40. Is the practice extending, of taking waters from surface-drainage?—Yes.

41. What, in general, is the value of such water, as compared with the water from rivers?—In general, where the water is principally flood-water, it is very much softer; for instance, Manchester is about to be supplied with surface drainage-water, and the hardness does not amount to 1 degree. Liverpool has also a Bill for the same purpose, and the water there will be under a degree. Sheffield likewise, to a certain extent, is supplied in the same way.

42. Have you ever been called on to examine certain waters in or near London?—Yes, at Richmond; I found the water from Richmond Park to be 8 degrees, and that from the Richmond Water-Works, taken from the Thames, to be 13 degrees of hardness. The surface water from the Bagshot sands is generally very soft, varying from less than one to two or three degrees of hardness. The hardness depends much on the nature of the soil. If I knew the nature of the rockons which the water falls, I think I could indicate what would be the degree of hardness. As far as I have seen, I have found surface waters decidedly softer than river waters.

43. As much as from a half to a third, the hardness of river water?—Yes, frequently; but it in a great degree depends on the geological formation. If there be no peculiarity of formation to make the water hard, surface-waters will be generally much softer than river-water.

44. Have you examined the drainage-water from land drains, that which is called shallow spring-water; and do you agree that this kind of water, properly managed, would have advantages even over the surface-water?—It would be all the better and clearer from having passed through a bed of vegetation, which would serve as a natural filtration. I should have no fear of surface-water (if it were carefully covered in) for the use of a town on a large scale, because it is found that in standing much of the impurity purifies itself by a natural process, and falls down.

45. Is it not the general practice now, where ground can be obtained free from building, to obtain a water supply from the collection of surface-water?—The chief supplies I know of lately are such, and they give not only sufficient in quantity but, on the whole, the best in quality.

46. Has the effect of drainage on surface-waters come before you?—No; I only know of Professor Wilson's analysis, showing the effect of land drains. I think you run the risk of getting a large amount of saline matter in water which is taken too near large towns. Suppose you select a piece of ground which is highly manured and lined; it has been shown that the kind of manure used is clearly exhibited in the

drainage-water of the field, and Professor Wilson recognized, by analysis, what each field was manured with, his object being to show that the fields were actually robbed thereby of the valuable qualities of the manure. I would sooner take the surface-waters if you could take them from a large extent of hill ground away from habitations, and consisting of non-calcareous formations. The recent observations of Professor Way have shown that claying soils have the power of extracting certain of the soluble saline ingredients of water, others of purifying them to a certain extent.

47. Are you not aware that it has been stated that the water which has come down the colour of strong black tea, has, when passed through a bag of peat, become quite clear, whereas no sand-filter would materially alter it?—I am not aware that peat does so, but charcoal, and even certain kinds of trap-rock, possess this discolouring property.

48. As far as positive experiments go, the advantage is in favour of surface-waters?—Yes, if you have them economically, plentifully, and from proper localities. If you have a district very highly manured, I doubt the advisability of trusting to this source of supply.

49. The river-water may be said to be of two sorts, field-waters, and the waters from springs?—Yes it is so.

50. Suppose ground were obtainable near London of 100 miles square of sandy or gravelly quality; should you have any doubt that water superior to the Thames water could be obtained?—I should not like to give an opinion without inspecting the district. If you refer to the Bagshot sand, I may state, that having examined the district, I do not see any chemical reason why its water should not be of excellent quality, as it is of undoubted softness.

51. Is it a general conclusion as to Thames water, that it is above the average in organic matter, and that sewage water, in particular parts, is in excess?—I have no doubt of it.

On the AIR and WATER of TOWNS. By ROBERT ANGUS SMITH,
Ph. D., Manchester.

Having been requested to examine into the variations in composition of the air and water of towns, I send the observations which I have made upon the subject.

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It has been long believed that the air and the water have a most important influence on our health, and superstitions have therefore constantly been attaching themselves to receptacles of the one and emanations of the other. The town has always been found to differ from the country; this general feeling is a more decisive experiment than any that can be made in a laboratory. Although men of high standing have been found to deny that any difference exists between the air of the worst towns or the most crowded rooms and that of the open country, it seems to be only a proof, that men accustomed to experimental inquiry are apt to forget the value and force to be attached to those apparently less rigorous observations which the senses are constantly and unconsciously making, and to believe only that which can be demonstrated by the grosser processes of a laboratory. Most men would be satisfied of the impurity of an atmosphere through which a blue sky could never be seen of a blue

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colour, or where a bright cloud appears of a dingy brown ; but there are men who take this air into glass receivers, and because they detect no new substances or strange compounds, they deny that there is any peculiarity. I have known persons from the highlands of Scotland who felt in going into Glasgow as we do when going into a glass-house or forge, and who could not be persuaded to stay, unless they remained long enough to find some advantages before unknown to them. The inquiries made by the Sanitary Commissioners have completely established the fact that crowded towns are dangerous places ; and although it is still an open question whether a well-regulated town or country life be the more healthy, it is sufficiently established that our towns have subjected themselves to many dangers, which we in self-defence are feeling compelled to try to avert, by acting according to natural laws as far as their acquaintance has been made.

Most persons must have felt that a rapid entrance into a large town, especially a manufacturing town, was also an entrance into another climate. An inhabitant of the sea-coast or of the hills perceives it rapidly, and the effect on them is often decidedly bad ; to those accustomed to it a few hours are found to be enough to cause them to forget the atmosphere which in their holiday excursions had caused them such delight. We are apt in these cases to assign other reasons for the feelings experienced, and to attribute much to the change of scene and occupation ; and I have read it not long ago asserted, that the air in the streets of London and of the tops of distant hills, probably differed only in the temperature.

Priestley found that after shutting up a mouse in air a considerable time it seemed to become weak and to be slowly dying, but if he put a fresh mouse into the same air at this period it instantly died. We can bear the gradual deterioration with ease, but we often find ourselves surprised at the state of the air in which we find our friends sitting, perfectly unconscious of any want of attention to their sanitary state.

The air has often been called a general receptacle for all impurity ; Nature has made it a universal purifier by giving it so large an amount of free oxygen. It is oxygen which purifies, and bodies which are impure have a tendency to volatilize, after which they become pure.

No doubt the air of a town contains a portion of all exhalations which arise in a town. These are such as come from living bodies in the first instance ; exhalations which can never be got rid of, but which it is probable are not at all dangerous, unless accumulated. There are also exhalations from the refuse matter of animals, and from combustion of fuel. These are the chief points. Various manufactures give out various effluvia, and no man that has walked through a large town with attention can have failed to perceive that no street is entirely free from effluvia, and that every one seems to have a peculiarity of its own.

The smell is a delicate guide to this, and although custom causes us to forget that odour to which we are much exposed, a frequent change gives us still more acuteness, and both houses and streets may fairly be complained of when the inhabitants are little aware of it.

That animals constantly give out a quantity of solid organic matter from the lungs may readily be proved by breathing through a tube into a bottle, when the liquid or condensed breath will be collected at the bottom of the bottle ; or by breathing through a tube into water, when a

solution of the same substance will be found in the water. This would scarcely require proof if we considered that breath so frequently has an organic smell; perhaps, rather, it always has an organic smell, and when it is bad the smell is often offensive, containing decomposing organic matter.

If this condensed breath be put on a piece of platinum, or on a piece of white porcelain, and burnt, the charcoal which remains and the smell of organic matter will be conclusive. If it be allowed to stand for a few days (about a week is enough), it will then show itself more decidedly by becoming the abode of small animals. These are rather to be styled animalcules, and very small ones certainly, unless a considerable quantity of liquid be obtained: they may be seen with a good microscope. Animalcules are now generally believed to come from the atmosphere and to deposit themselves on convenient feeding-places; that is, they only appear where there is food or materials for their growth, and they prove, of course, the existence of that continuation of elements necessary for organic life. At the same time, their presence is a proof of decomposing matter, as their production is one of the various ways in which organized structure may be broken up. Such a liquid must of course be an injurious substance, giving out constantly vapours of an unwholesome kind.

I mentioned some time ago that I had got a quantity of organic matter from the windows of a crowded room, and I have since frequently repeated the experiment. This matter condenses on the glass and walls in cold weather, and may be taken up by means of a pipette. If allowed to stand some time, it forms a thick, apparently glutinous mass; but when this is examined by a microscope, it is seen to be a closely-matted confervoid growth, or in other words, the organic matter is converted into confervæ, as it probably would have been converted into any kind of vegetation that happened to take root. Between the stalks of these confervæ are to be seen a number of greenish globules constantly moving about, various species of Volvox, accompanied also by monads many times smaller. When this happens, the scene is certainly lively and the sight beautiful; but before this occurs, the odour of perspiration may be distinctly perceived, especially if the vessel containing the liquid be placed in boiling water.

My analyses of this body are not yet ready, further than that it contains the usual organic elements.

If air be passed through water a certain amount of this material is obtained, but I have found it difficult to pass a sufficient quantity through. If it is made to pass rapidly, absorption does not take place, and evaporation of the water is the consequence; if it passes slowly, it requires many weeks to pass 100 cubic feet through a small quantity of water. I continued the experiment for three months, but although I obtained sulphuric acid, chlorine, and a substance resembling impure albumen, I did not get enough to make a complete examination; and indeed this could not be expected, as I found that in that time less than 1,000 gallons of air had passed through.

When this exhalation from animals is condensed on a cold body, it in course of time dries up, and leaves a somewhat glutinous organic plaster; we often see a substance of this nature on the furniture of dirty houses, and in this case there is always a disagreeable smell perceptible. I

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have no doubt that this is a great cause of the necessity for constant cleaning, which experience has found and made to be a very general practice in England and elsewhere. In other words, it is a reason why that which is not cleaned becomes dirty, a question which I have often felt great difficulty in answering.

Water is necessary to the spontaneous decomposition of animal matter, and it is probable that in a warm climate this coating of walls and furniture would not be so dangerous as with us, where everything is exposed to moisture a considerable part of the year. In a warmer climate it will probably be diffused more into the atmosphere, and not be so much retained as it is by the moisture which dissolves it or to which it attaches itself.

It will probably be found that this substance is not poisonous if taken into the stomach, but it is known to be poisonous breathed into the lungs, as we know crowded rooms are. The quantity is small that we do breathe, but at the same time we must remember that it is diffused in air, and has therefore a surface as extended as the volume of the air in all probability; and we know that a cubic inch of sulphuretted hydrogen will scent at least some hundred cubic feet of air.

As this substance of which we speak is organic, and contains carbon, hydrogen, and nitrogen, with other elements, it is capable of oxidation; and it no doubt is continually undergoing oxidation in the air, probably forming carbonic acid, water, and ammonia. It is also not unlikely that this is a greater source of the ammonia of the atmosphere than the mere foetid decomposition of animal matter, which does not occur to a large extent in nature, provision being made for its removal by animals, and by vegetation especially.

Organic matter in contact with water constantly gives off an odour of some kind, and especially if heated, so that it would appear as if steam or vapour were capable of taking up much more than that which we call volatile matter.

If organic matter be allowed to decompose in the air it gives out carbonic acid, ammonia, sulphuretted hydrogen, and probably other gases. Priestley has shown that if it decomposes in water it gives out an inflammable gas. If, however, it be exposed to the action of soil, other circumstances being favourable, it is converted partly into nitric acid.

None of these cases occur purely in our towns, but all of them occur to some extent. Carbonic acid and ammonia occur in all reservoirs of refuse, and sulphuretted hydrogen occurs also in abundance. It was once very perceptible in London, as Sir Kenelm Digby complains much of the state of the streets, when silver could not be kept clean in his day. This may be observed now in many towns, and is, in fact, not uncommon. This is a disagreeable smelling gas, and wherever it is abundant, will be easily detected by the nose. It may be detected readily in many courts and alleys, also at the mouths of sewers, and in some parts of the Irwell and Medlock, at Manchester, where they are filled with organic matter and alkaline, and earthy salts. Ammonia generally accompanies it, so as to diminish its bad effects.

Ammonia itself is probably of no injury unless in excessive quantities, and may be considered as one of the most wholesome forms in which nitrogen and hydrogen, as gases, pass into the air. A decomposition

such as this occurs ordinarily in towns, as there is a certain exposure to air always.

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In cases where there is no exposure, or, at least, when the substance is in water, inflammable gases are produced, as Priestley has shown, and Liebig has, to some extent, explained. It would seem as if, when decomposition commenced, oxidation of one portion necessarily took place, leaving the other portions without oxygen, unless in cases where an abundance could be obtained. Dalton found the gas from the floating island at Derwentwater to contain carburetted hydrogen and nitrogen. The carbon and the hydrogen are deprived of oxygen entirely, whilst more oxidized bodies, as carbonic acid and humus, are left, the latter body to be in time entirely oxidized, as Liebig has shown. Whether the nitrogen comes off alone or as ammonia, the same division of a substance into oxidized and deoxidized occurs, as we see, in the fermentation of sugar, where carbonic acid a body oxidized, and alcohol a body to a great extent deoxidized, occur. We have only to suppose compounds of carbon, hydrogen, and nitrogen, coming from decomposing matter, to show us the great danger. It is not to be trusted that these bodies always appear in the mode of combination mentioned here; their modes of combining are various, and these elements form the most active poisons known to us.

A certain amount of moisture is almost essential to the escape of odour from many bodies; it probably arises from two causes. The vapour of water is a vehicle for organic matter, and water favours decomposition in bodies, so that as they decompose the vapour is given out. From whatever cause, it will be found that moisture rapidly facilitates the escape of odour. Mineralogists avail themselves of this when they breathe on a mineral, and then ascertain the smell. The moisture of an evening, or even artificial moisture, causes the flowers to give their scents, and the moist state of the atmosphere before or after a shower, causes also a great fragrance in a flower-garden. But whilst this is caused, the same laws are operating for injurious effects, wherever there is a reservoir of putrid matter, for then the exhalations are also abundant, and bubbles may be seen to rise from filthy water. It is not improbable that the state of the atmospheric pressure may cause this, as Mr. E. W. Binney has shown that the gases in coal-pits are caused to escape rapidly during a lowering of the barometer. Bodies that are moist will therefore give out more organic vapours; if there be abundance of water, as in a lake, the vapours would to a great extent be dissolved, even if the same kind of decomposition were to proceed as in merely moist or marshy ground. We might expect then that soil, if moist, will give out, not pure vapour of water, but water with organic matter in it. Wet soil is a little acid generally, and if very acid is bad land, sour as it is called; but if made alkaline, either by the direct adding of ammonia, or by decomposition producing ammonia, it becomes fertile. If any alkali be added, which gives out ammonia by decomposing the humate of ammonia in the ground, the same state of fertility is attained. This end is generally attained by adding lime. This state of almost neutrality of the soil is also regulated by nature, and a fertile alkalinity obtained by the rapid decomposition of organic matter through moisture and heat. In this alkaline and warm state more vapours will of course be given off, and the ammonia will assist in the removing of organic matter into the air. How far this

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occurs on sowed land has not yet been seen by me satisfactorily ; but on peat land the ammonia formed is abundant in hot weather, so much so as to be perceptible directly by the senses, and to take with it in solution a large quantity of humus and salts of humus, containing food for plants, as I showed in a paper to the Philosophical Society of Manchester.

I mention this to show how organic matter may be lifted into the air, and why hot weather promotes it ; also, I wish to show how various this matter must be in its properties, as all vegetable solutions give out a certain amount of matter from them.

To ascertain if organic matter were really to be got from such vapours from land, I collected some dew by condensing it on a glass cylinder, and allowing it to drop into a glass below. The fewness of the evenings favourable for the purpose this year, has, of course, retarded me. I saw plainly, however, that the substance thus obtained from the dew was very different from that obtained by condensation in a warm room ; whereas that from a crowded room was thick, oily, and smelling of perspiration, capable of decomposition, and productive of animalcules and *confervæ* ; the dew was beautifully clear and limpid. When boiled down, the odour was not disagreeable, and I may say, not remarkable ; but when the small portion of solid matter, which remained dissolved in it was exposed to heat, the smell was that of vegetable matter, with very little trace of any nitrogenized substance. It was also rather agreeable than otherwise. The dew was collected in a flower-garden, and I have no doubt in favourable weather of being able, in dissimilar situations, of getting it of different characters. It is not improbable that the matter in the dew may be a measure of the amount in the atmosphere ; if so, the decided difference between that of the country and that of crowded rooms is to be remarked, and may probably form a good guide towards a knowledge of comparative purity of atmosphere.

In walking along the fields on an evening when there is much dew, it may be observed how much effect a dry soil has ; indeed, I might almost say the climate of a field will be found to vary almost every yard. Every cause of cold, the formation of a drain, the lowness of any spot, its being higher or more level, or more sheltered, is indicated by this delicate thermometer, the rise of vapour, and the perception of cold. If we ascend higher the same is seen on a larger scale—on miles instead of yards. A house may be in a clear atmosphere, and the lawn before it in an impenetrable fog. One foot in height makes a difference, and one foot also of level distance, if the ground should differ in quality. The damper places give us a feeling of freshness, and cause also a slight irritation of the nose. Every wall causes a certain amount of dampness ; and even in a windy day, a leafless hedge will protect one side from evaporation. In these respects, therefore, we may say truly, that every field or house in the country, as well as I believe every house in the town, has its own peculiar climate.

The effect of wetness on the atmosphere of a town is very great ; if we observe the smoke on a dry day we find that it rises, and if there be a little wind it is carried out in distinct black lines, leaving the air below comparatively pure. If the day be dull and wet, the smoke instead of being carried away is poured out directly into the streets, and a spectator at a short distance sees a basin of black fluid, if the town be in a valley, or a heap gradually diminishing towards the circumference as it falls into

the adjacent country. It may be replied, that the diffusion of gases would prevent this, but again it may simply be said that it does not prevent it. Besides, the smoke is not to be considered as a gas, the black portion is carbon and tar. If the carbon is wet, it becomes, like all other spongy bodies when filled with water, heavy, and of course falls down. The carbonic acid will no doubt be diffused more, but it also is strongly attracted by water, and must not be viewed as a pure gas, such as oxygen or nitrogen. Probably this is the reason of the very disagreeable state of our towns in damp gloomy weather; it is such weather as does not allow the town to be ventilated. The same does not occur on a thoroughly wet day, when the matter is carried fairly down into the streets, and a certain freshness is perceived.

Rain amidst smoke is just such a liquid as we might expect; it is a mixture of soot in a finely-divided, apparently dissolved state. It is, however, not dissolved, and by boiling down may be got free. It is not easy to tell exactly the composition of the rain; for, although I have examined it, and obtained many products in it, so much may be said to come from other sources when water is collected near houses or near the ground, that I have often suspected some source of error. However, I think if we take that rain which is collected on a very wet day, after many hours of continued pouring without wind, we may consider that we have got the purest specimen. This was collected frequently, and having obtained it so often I am now satisfied that the dust really comes down with the purest rain, and that it is simply coal ashes. No doubt this accounts for the quantity of sulphates and of chlorides in the rain, and for the soot, which are the chief ingredients. This rain is also often alkaline, arising probably from the ammonia of the burnt coal, which is, no doubt, a valuable agent for neutralizing the sulphuric acid so often formed. It must, however, be frequently acid with sulphuric acid, although I have not found it so, as I have traced sulphurous acid in the atmosphere frequently, walking through some miles of streets to come to its source. The source, however, is not easily obtained, because I believe it does not fall till at some distance.

The rain-water at Manchester is about $2\frac{1}{4}$ degrees of hardness, harder in fact, than the water from the neighbouring hills, which the town intends to use. This can only arise from the ingredients obtained in the town atmosphere.

But the most curious point is the fact that organic matter is never absent, although the rain be continued for whole days. This matter is capable of promoting animalcular life to some extent, and small specimens may be seen moving solitary in it. If allowed to stand in a bottle, this may be more clearly detected. On this matter I must say more at a future time.

My chief wish is to show that the general notions entertained by persons as to the air of towns are not without the support of what is called scientific observation, although at the same time the effects on life are greater than chemists by any observations could have made out.

Vogel and others have found organic matter in the atmosphere; and Dr. Southwood Smith, in looking for matter which might produce fever, found an organic substance, I believe, in some of the streets of London. I give only in detail what I have myself observed.

If this matter should from any cause be exposed to a decomposition

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more rapid than usual, we have before us a state of things worse, because more general than a bad sewer, and can account for many diseases. I am, therefore, disposed to think of it as Lord Bacon thought of the cause of jail fever:—"Out of question such smells consist of man's flesh or sweat putrefied. There may be great danger of such compositions in great meetings of people within houses; for poisoning of air is no less dangerous than poisoning of water. And these empoisonments of air are more dangerous in meetings of people, because the much breath of people doth further the reception of the infection."—Bacon's *Sylva Sylvarum*.

The state of the air is closely connected with that of the water; what the air contains the water may absorb, what the water has dissolved or absorbed it may give out to the air. Whatever the rain meets with in its course from the surface to the wells of a town is, if soluble, dissolved in the water. The enormous quantity of impure matter filtering from all parts of a large town into its many natural and artificial outlets, does at first view present us with a terrible picture of our underground sources of water. But when we examine the soil of a town, we do not find the state of matters to present that exaggerated character which we might suppose.

I have often been struck with the extent to which water may purify itself. At Bala, on the hills, the water is brown; in the lake it is still coloured, but in its course it becomes beautifully clear. A still stronger instance may be observed on the hills beyond Bolton, the water in which is of a deep brown; when it falls into the reservoirs just below, it ceases to be very dark, although still too brown for agreeable use; but when it has run a few miles it ceases to be remarkable, and is often perfectly pure. I was struck also with the fact that filters do not become dirty in proportion to the amount of impurity which they seem to remove. The sand at the Chelsea Waterworks contain only 1·43 per cent. of organic and volatile matter after being used for weeks, and cannot be considered as impure in a high degree.

In 1827, Liebig found nitrates in twelve wells in Giessen, but none in wells 200 or 300 yards from the town (*Annales de Chimie*, vol. xxxv.) Berzelius made similar observations at Stockholm. In 1846 and 1847, I examined about 30 wells in Manchester, and found none free from nitrates; many contained a surprising quantity, and were very nauseous (*Mem. of the Chem. Soc.*).

Wells in the country generally contain organic matter, and in the town the organic matter is oxidized into nitric acid, as if it required a certain intensity to promote the action. It is very probable that this acid is an effect of restricted oxidation, occurring as it does with such excess of organic matter, and, although near the surface, still under hard pavements and soil where there is also little flow of water. It might, however, be viewed as an oxidation, with excess of oxygen also where the large extent of surface presented by the porous materials gives an increased facility for oxidation, or rather presents compressed oxygen, so as to be more effective.

It will be of interest to know what becomes of the carbon and hydrogen in these cases, if they are removed together. These nitrates do not occur to any extent in purifying large bodies of water, nor do they occur in filtering through rocks or sand as in nature, but they occur in more close situations, under streets and houses, and in undrained ground,

according as it is saturated with animal matter. It is found in sewer water, in the Thames water, and in all dirty streams into which sewers empty themselves: perhaps the reason of its not being found in larger quantities in streams from drained land is simply the want of animal matter, or it may not be formed more rapidly than the plants can use. It is found, however, in wells which are situated in well-manured gardens, and in all wells at the backs of houses, without any exception yet met with by me.

The wells of private houses, and we may say wells generally, are placed in that spot which of all others is the worst, the cesspools and the wells always too near, generally close to each other. I was first led to examine this from a complaint made in Manchester, where a case of this kind furnished water of an oily appearance, containing about 90 grains of matter in a gallon, and being excessively disagreeable. The same well was examined in summer, and the matter had risen up to nearly an ounce in a gallon. The well was of course not fit for use in this state.

In the same neighbourhood was a churchyard, and around it I examined five wells, one of them especially, sufficiently far removed from cesspools to make me believe that the churchyard was the only cause of the impurity. The wells of London all contain nitric acid to a certain extent, but they vary exceedingly in the amount. The following have only a small quantity:—Exchange, Rood-lane, Eastcheap, St. Paul's churchyard, Tower-hill, Covent-garden, Lincoln's Inn-court, St. Clement's Strand, Aldgate Pump, and Bow Church. It seemed to me, from the situation of the old well at Clerkenwell, that it was very well fitted for obtaining nitrates, and on examination it was found to be exceedingly well-filled with earthy salts, containing 148 grains of solid matter to the gallon, of which several were nitrate of lime. The water of this neighbourhood would contain about 20 grains to the gallon in a natural state, if we may judge from the water generally found in the valley of the Thames.

Another well in North-street, Tottenham Court-road, was examined, as from the state of the drainage I expected it to contain a considerable quantity of earthy salts. Here also I was not deceived, having got 130 grains of sulphates, chlorides, and nitrates in a gallon; the water itself a fluid which I could not swallow.

There is then a constant formation of nitric acid under towns. It is a little surprising that organic matter, properly so called, should not be found in those wells; the nearest to a source of organic matter do actually contain the least, because in these cases it is more readily converted into nitric acid, which may very properly be called here oxidized organic matter. At the same time, also, it must be remembered that the nitrates decompose any organic matter present if heat be applied, so that no blackening of the residue can be perceived. Those wells of London first mentioned do not contain much of these salts, but sufficient to deprive them of organic matter, as no vegetation is to be perceived in them, even by a microscope, after a long period. If, however, a mere trace of nitric acid be found, as in the well of Tower-hill, a green matter deposits on standing. This perfect freedom from animal or vegetable growth is a ground for suspicion, also, of nitrates being present, as there generally is a little green matter found in the purest waters, unless they pass through great depths of sand or gravel, as in the new red sandstone, where the

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water, if taken from a deep well, is entirely free from everything but inorganic salts.

The fact of some of the wells being freer than others from these salts is a proof of a dependance on the state of the soil, and I doubt not that the drainage has the greatest effect on the change made. Some of the mud taken from under a street in Manchester, where a sewer had been allowing some moisture to ooze out, was found to contain nitrates also in considerable quantities, but the sand and gravel below was nearly dry, and perfectly free from nitrates. Although it is very probable that nitric acid is formed most readily in the sand, yet it is also more readily carried away, and after much rain we cannot expect to find such a soluble salt remaining.

As to the source of this acid, I made some experiments last year for the Metropolitan Sanitary Commission, which I may here relate. My object was to get an idea of the nature of filtration. A jar, open at both ends, such as is used with an air-pump, was filled with sand, and some putrid yeast, which contained no nitric acid, was mixed with pure water and poured on the sand, allowing it to filter through. The product of nitric acid was abundant, so much so, as when boiled down to give it out at once, on the addition of protosulphate of iron and sulphuric acid, making the red fumes of the peroxide of nitrogen apparent without the aid of any very refined test.

Charcoal was tried for the same end; it did not answer, although allowed to act for two months; it was put into a large Hessian crucible, and the liquid allowed to trickle through the crucible and charcoal together.

Ox-flesh was in this manner oxidized into nitric acid, after allowing it to putrefy. This result could be obtained by means of an ordinary household filter, if the time allowed were long enough, and other conditions favourable. The same was done on a smaller scale, by allowing nitrogenous organic matter to stand over spongy platinum.

No doubt this is a very important provision of nature for the prevention of the evil consequences of putrefaction; it is the complete destruction of all dangerous gases, and the perfect purification of the most impure substances; whether it be advisable to drink water having much of this oxidized matter in it is another question. We see, however, in this the two great agents of sanitary improvement at work for us, the air and the water acting through the soil; whatever goes through such an ordeal is made pure. The drainage of a country is therefore that which removes the evil effects of decomposition as well as the excess of moisture.

The action of air and water on *surface* is then a powerful one, and probably is capable of doing many marvellous things with the substances given to it to treat. The effect produced on sulphuretted hydrogen is no less decided. A bottle of strong sulphuretted hydrogen was poured upon the sand-filter, and sulphuric acid was the result, with sulphates formed of bases which it had washed out of the sand. Sulphuret of ammonium filtered through sand contains sulphuretted hydrogen no longer, and will not blacken lead, so powerful is this kind of oxidation.

Water from a pump in a yard not far from me gave out a disagreeable smell of sulphuretted hydrogen which filled the neighbouring houses. This I found the persons accustomed to filter and to drink:

the sulphur was converted into sulphuric acid, and the water was actually made quite pure.

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These are no doubt some of the advantages of a filter; if so, we are then to consider that a filter acts according to its cubic dimensions, and not by its surface only. If the porous rocks have thus the power of oxidizing sulphur and nitrogen, we may then ask, have they not also the power of oxidizing carbon? Hydrogen is no doubt oxidized, the ammonia being broken up so as to form oxides, as nitric acid and water.

We see that natural filtration, with abundance of room and free movements, dissipates the organic matter, and nitric acid too, if ever formed. The time allowed for filtration being so short, that is, the time from the falling of the rain to the appearance of the pure water from the spring, we cannot suppose that vegetation accomplishes the purification, whilst there is no deposit of impurity apparent to account for the change. It seems to me that the action of the compressed air on the surface of bodies is sufficient to answer this question, and that this matter is removed by a process of oxidation. It was Saussure who showed that humus can unite oxygen and hydrogen; Liebig has shown that humus is constantly capable of combining with oxygen, and calls it a constant source of carbonic acid. When then we see water not very free from organic matter enter a rock and come out free from organic matter and sparkling with carbonic acid, leaving no visible organic impurities behind it, we may safely conclude that the oxidation of the carbon has effected it; this then is a higher degree of purification than the oxidation of the nitrogen, which is probably allowed to go free.

Processes such as these are going on constantly wherever water is filtering. On land generally such things must be constantly occurring. The ditch-water of our fields is a very different water from the river-water into which it runs, or even of the drains a few feet only below it. Some water taken from a ditch in the neighbourhood of Manchester became in a few days a complete mass of life, and the many specimens of animalcules in such water make it a good subject of study. Water from a drain three yards deep does not, however, contain this immense quantity of organic or organizable matter, depositing only some green matter, partly animal, partly vegetable.

When water flows from hills or elevated land in a river-course, it undergoes changes according to the nature of the bed, and also according to the number of towns on its banks. As an instance of this, I will follow the river Thames from its sources to London Bridge without giving the details of analysis here, but the character of the changes as known to me.

Water from the Seven Springs, or from Thames Head, or Andover Ford, proceeding as it does from the rock, is in the perfectly oxidized state of which we have been speaking; it contains a great deal of carbonic acid and of lime in solution. When allowed to stand, it preserves its great purity (or clearness of appearance rather) any length of time, not appearing to change. Such water as this requires no managing; it would be a good thing if it could at once be introduced into houses; it is in fact spring-water from the rock, and such water is known to be always good, unless the rock contain deleterious substances. Rocks of course are found which give out a water much freer from lime than the water of

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the Thames sources; such, for example, as those between Lancashire and Yorkshire. At a place called Swineshaw on one of these hills, a stream gushed out from the hard and insoluble rough rock of this place, having the purity of average distilled water, with a sparkling appearance and agreeableness to the palate which distilled water never has. It is under one degree of hardness of Clark's test. No doubt there are other streams as good, and the whole of that and similar districts gives the most beautiful water. The same may be said of a great deal of the water of North Wales, and in such places as have very insoluble rocks. I said as pure as the average distilled water; it may not be known to all persons, that a number of distillations are necessary in order to obtain pure water. For this purpose, a water from a great depth, or a spring-water from a rock is best to use, as there is less volatile and organic matter in it; the first distillation of the usual waters about Manchester giving a very imperfect product.

Purity of water and fertility of soil are not to be expected together, if we may judge from the facts above. Freedom from both inorganic and organic matters is got only in water from very insoluble rocks, which are not the fittest for vegetation; or it is got where there is much sand or gravel containing little soluble matter, and of course little food for plants. If, however, these strata be together, as soon as the water comes from the insoluble to the soluble it will change.

The Thames water is at first pure, as far as freedom from organic matter occurs, and takes its course through a rather level country. The stream is soon filled with plants; and at Kemble the water has already taken up some organic matter, enough to form a slight green deposit on standing. The water here is still beautifully clear, and is good water; it is 15.5 degrees of hardness.

When we come down to Pangbourne, the water cannot be said to have become much worse; it is still so pure as to require a considerable time to form a deposit, and that only small, containing a few plants and some small animalcules from $\frac{1}{2000}$ to $\frac{1}{3000}$ of an inch. Here there is a slight but still decided trace of organic matter from animals. There has been an increase in the hardness also.

		Grains of Soap.
Seven Springs	12.75 of hardness	262
Andover Ford	13.88 ,,	283
Thames Head at Kemble . .	15.5 ,,	312
Church at Cirencester . .	15.7 ,,	315
Reading	16.5 ,,	340

Pangbourne was only 15.4 in November, 1847; the others are of February, 1848, when the water was harder down to London. There is seen here an increase in hardness, and there is also an increase in soluble salts not contributing to the hardness. At Seven Springs the hardness is equal to the whole amount of insoluble salts and a fraction more, which may arise from an excess of carbonic acid.

	Grains.
At Seven Springs inorganic matter in a gallon	12.25
At Pangbourne ,, ,,	22.33
At Reading ,, ,,	23.114

At Windsor, animalcules begin to show themselves more prominently in the water, and these rather large hydatina. There are also at Reading and Oxford some of the smaller green naviculæ, and several other smaller

green bacillaria. Oxford water had more of these than Reading, and also a large amount of matter in solution; it is probable that the soil through which the Isis flows is rather different from the other part of the Thames. The river was rather high at the time.

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From Richmond downwards the case is much altered, and the water, although clear, gives after a time, a brown flocculent deposit, entirely distinct from the mud deposit, which has been carefully removed beforehand. This flocculent deposit contains many animals, large and gelatinous-looking; also below Chelsea, and chiefly below Hungerford-market, little eels, "*Vibrio fluviatilis*," about $\frac{1}{30}$ th of an inch long. The side of the vessel in which the water stands is covered with another precipitate quite distinct, not flocculent but hard, of a light brown, and chiefly towards that side of the vessel which is exposed to a moderate light. This precipitate is often mistaken for oxide of iron, which it strongly resembles, and to which it may probably owe its colour; but it may be known to differ from a simple oxide by the addition of muriatic acid, which gives it a beautiful green colour. When seen through the microscope, the colour will be found owing to the little dots of green which mark the polygastric character of these animalcules. These little creatures (chiefly I believe the "*Navicula fulva*") are covered with a crust of silica, and by boiling in muriatic acid the silica may be separated from the other portions which are soluble. In this way phosphoric acid, lime, and magnesia, may be separated with ease; and this will, I think, be found one of the best modes of collecting the phosphoric acid from water of this kind. The quantity of silica is very great, as the number of these little loricated animalcules prove. Life of this kind may at once be considered as a proof of the presence of all those elements essential to animal life generally, as these animalcules do not appear unless in the wreck of other animals or vegetables, whose requirements as to food are well known to be confined to certain elements. The abundance of silica is not from the upper part of the Thames, but no doubt from the sewers, proceeding from the decomposition of wheat, oats, &c., and may be viewed as a necessary consequence of the consumption of bread or any grasses used by cattle.

There is then a great deal of matter in a state capable of being converted into living forms; this matter is not in suspension merely, but in solution also. A large quantity of organic matter is precipitated in contact with clay and mud in the Thames, but a great deal is also in clear solution. This matter must be organized, of course, to some extent, and probably contains albumen; it seems to me that it is albumen which I have found in it, certainly a body much resembling it. The same may be obtained where many large animalcules appear; probably the quantity will be found the same whether the animalcules be formed or not. The clear solution becomes a mass of growth very soon, if the matter contained in it be organisable. Organic matter may exist in a state in which, even under favourable circumstances, animalcules are not formed, as I have found to be the case with some kept for some months in water. A similar thing may take place with the Thames water at London; if kept in close jars of earthenware, no change is produced in the organic matter; as soon as removed into glass bottles, a rapid change occurs, and a lively scene is produced of animals and vegetables. Kept in the dark, the water dissolves much organic matter, and becomes yellow; the water

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over the living matter is clear, or, in other words, the dead matter is to some extent soluble in water; living matter is, of course, not capable of having its parts broken up by mere water, and is insoluble. This growing of plants and animals is, therefore, a good mode of cleansing water, when space and time are abundant, as in the larger operations of nature, but unfitted for waterworks, where neither are very ample. The mode of cleansing used by Water Companies is one employed by nature also, as all the water which falls on the soil is filtered by passing through; that is to say, it first becomes exceedingly impure, being filled with matter from the surface, and gives a part of this out again in passing through the soil. Water becomes hard very rapidly on the surface of some land, and it is strange how it adheres to its standard of hardness, remaining for a great part of the year the very same. A rapid shower, producing a sudden overflow of a ditch in a field, was found to be composed of water of 12 degrees of hardness and 16 grains of solid matter to a gallon; this same specimen also swarming with life.

I supposed, and others have done so also, that a shower would produce a stream of water softer than what slowly trickled through the ground; but on examining the water at Longendale in rainy weather it had actually risen 2 degrees. The Thames was also considerably softer in November, 1847, after some dry weather, than in February, 1848, after long rain. At Chelsea, in November, it was 13·44 degrees of hardness, taking 275 grains of soap test; in February, 14·94, taking 302 grains. It would appear that rainy weather softened the ground, and so made the matter more soluble, or the winter frosts broke up the ground and attained the same end. This latter reason is agreeable to the general opinion concerning the use of a frost, and the fact may also be taken as a corroboration of the opinion. The hard water will, of course, be better able to feed land with its soluble manures; or, if we choose to express it otherwise, the plants will more readily feed, finding the food more soluble.

However true it be that all soil filters water, it is no less true that any admixture of clay is detrimental. The clear streams are found in rocky countries, and, as was before mentioned, and well known generally, on barren land.

We have seen that the water of the Thames at London, is capable of decomposing with the disagreeable products alluded to, and when put in casks for sea-use we hear of a fermentation, with the formation of nauseous vapours, and of an inflammable gas. We have already seen that Priestley found inflammable gas from organic matter decomposing in water, and, in fact, it is a thing universally observed. Priestley said, however, what is not so much observed, that the air from the decomposition of a cabbage in the dark was inflammable, whereas, that in the sun produced very little inflammable air, and was not so offensive in smell. The fermentation of water may, in fact, be looked upon as a simple proof of great organic impurity. Organic matter will decompose either by going into inorganic gases, as in the dark, or into organized bodies of another description, if there be light to favour growth. These considerations bring us to the mode of storing water, and of supplying water to houses. If there be a large supply of water in a reservoir, it will, if impure, clear itself by vegetation, according to what we have seen by experiment, and as is seen in nature. In this case a reservoir must

not be underground, but in the light; strong light and great warmth seem too much to assist chemical solution, the reservoirs should therefore not be so shallow as to allow this. However, there are probably few cases where water is to be so long stored; as to the usual cases, it may be said, that unless long storage is allowed, it is better that there should be as little as possible, unless the water is to be filtered before delivery. The reason of this is, that the course of purification of impure water is the worst state of all; even filtered water will not bear standing, because it also tends to purify itself still more by giving out in some form or other all its organic contents; and it is remarkable how the apparently purest water will deposit impure matter.

The same thing may be said of water stored on a smaller scale, as for private houses, there is no way of keeping it clear. If kept dark and cool, the change is retarded, and this is the best way for small quantities. It would be the best way for large quantities, also, if it were perfectly pure, as then no change whatever could occur.

But even when water is to be kept a day only, there is an objection to cisterns in most cases. If there be a little impurity deposited, the daily increase soon makes it a great impurity; and although the fact of the impurity remaining in the cistern be a sufficient proof that it has not been drunk or otherwise used, yet such a reservoir of impurity is constantly apt to be giving off some offensive matter. If the impurities be of the kind common in Thames water, and in the water of many of the Companies, or in the Manchester water, or that of some other towns, they are of a kind capable of producing animals very disgusting, and large enough to be seen sometimes by the naked eye. If even nothing but a green matter is perceptible, this is displeasing in itself, besides never being alone, but inhabited by numerous little creatures visible with a microscope, although not so disgusting as those to be met with in the flocculent precipitate of the Thames water. Underground cisterns in London, when supplied with very pure water, contain in them some of the most disagreeable of these living forms; and although apparently a good method of keeping water cool, it is a plan to which the impossibility of cleaning is a great objection. Even stone cisterns, however clean stone in itself may be, are often filthy receptacles of water, for which not the stone but the water is to blame. If wood be used, pure water can never be obtained; and the enormous amount of crenic acid formed, with the peculiar smell of rotten wood, which happens even in new barrels, form great objections. The reddish flocculent matter is also not without inhabitants, for which it affords a good shelter.

If I come to the conclusion that water should either be kept in large quantities or kept constantly running, it may be said this was known to every one; true, but when this happens, it is the business of science to explain why it is so; and if this be not done, there are constantly found some who deny the general impression until a proof be obtained.

Dr. Clark, who has done so much towards giving the country in general an interest in the purification of water, advises also the alkalinity of the water to be taken at the same time as the hardness. I have found it more convenient to take the fixed contents in a gallon of water. By comparing this with the hardness, we find the excess of impurities not affecting the hardness. To do this, and take the alkalinity also, would probably be the best mode of treatment. In the springs at the source of the Thames,

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the fixed matter and the hardness are equal, or nearly so, whilst in the Thames at London, the fixed matter rises as high as 26 grains per gallon, whilst the hardness is 15 degrees. This gradual increase of salts not affecting the hardness, is a good indication of the rate of impurity in the progress of the river, and is a great cause of making it a less agreeable draught.

From experiments which I have made on the cause of vapidity in water, I am led to believe that the salts of alkalies are some of the most common agents. Dr. Clark has shown the great influence of temperature on the taste of water, but it seemed to me not enough to explain the frequency of the occurrence of tasteless water.

Water with carbonic acid in it did not taste vapid when raised slowly to 100° Fahr., the acidity being sufficient to prevent it, as I believe.

Lambeth water boiled and cooled could not be made to taste as well as water which had not the same amount of salts in it.

Pangbourne water, although excellent, when boiled down so as to saturate the salts which are not precipitated by boiling, tasted even when cooled excessively vapid.

Soda-water with alkaline salts, when boiled, is excessively disagreeable.

Twenty grains of common salt cause a gallon of water to taste vapid, and two grains and a-half of saltpetre or nitrate of potash have a still stronger effect.

The nitrate of lime in the water of towns mixed with the common salt gives an extremely nauseous taste to water, and causes it also to taste somewhat soft, although possessing such a large amount of matter as I have mentioned. Acids control this taste; carbonic acid, we have seen, prevents vapidity. A few drops of any acid render water pleasanter in a warm day. Acidity is strongly allied to coolness of the taste, as general experience shows. Acid drops and oranges in hot rooms are used for this reason, and vinegar also by travellers in hot climates. A few drops of any acid, vitriol, for example, are used by the workmen in chemical works to improve the water in warm weather.

Alkalies cause water to appear soft. Beer which is called hard is acid, and becomes soft by adding soda; this is common.

The salts of lime seem to be the only salts which do not easily render water disagreeable.

I may conclude this paper with a short summary of what I have said about water and air.

Summary.—1. That the pollution of air in crowded rooms is really owing to organic matter, not merely carbonic acid.

2. That this may be collected from the lungs or breath, and from crowded rooms indifferently.

3. That it is capable of decomposition, and becomes attached to bodies in an apartment, where it probably decomposes, especially when moisture assists it.

4. That this matter has a strong animal smell, first of perspiration, and when burnt, of compounds of protein, and that its power of supporting the life of animalcules, proves it to contain the usual elements of organized life.

5. Organic matter of dew contains less nitrogen.

6. The slightly alkaline state into which soil is put at certain periods

of the year, give it a facility for emitting vapours ; whilst all vapours of water from organic matter contain organic matter.

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7. Water purifies itself from organic matter in various ways ; by forming nitrates, as in sewers, and in the neighbourhood of cesspools and churchyards, under streets, in manured grounds, and other repositories of organic animal matter.

8. This may be done in a laboratory on a small scale, where animal matter, by means of a sand-filter, may be converted into nitric acid.

9. In the larger operations of nature the carbon also is oxidized.

10. Sulphuretted hydrogen is also oxidized on a small scale by a filter, being converted into sulphuric acid.

11. A filter, therefore, as an oxidizing agent, acts in proportion to its cubic contents.

12. Water falling on the surface of the ground gets rapidly saturated with organic matter ; but in passing through the soil gets filtered, and the matter oxidized, making the porous soil and the air the great agents of purification in a country ; whilst drainage will act by removing organic impurity as well as mere water.

13. All wells near houses, and all wells in towns contain nitrates, which may be easily traced to sewers or accumulations and outlets of refuse.

14. The alkaline salts of towns increase the vapidness of water. They abound in river-water, which receives the refuse of towns, and cannot be filtered out. The difference between the hardness of water and the amount of water per gallon gives a measure of impurity, as it indicates other than the lime salts, whilst the lime salts affect least the taste of the water.

15. A slight acidity removes vapidness, and produces a perception of coolness in the mouth.

16. Water can never stand long with advantage, unless on a very large scale, and should be used when collected, or as soon as filtered.

On the SURREY WATER DISTRICT. By Dr. ROBERT ANGUS SMITH.

In compliance with directions from the Board of Health, I visited the proposed gathering grounds for water, which are situated in Surrey, stretching from Leith Hill on the south-east of Guildford, to Frensham, Farnham, and Alderholt Wood, on the west, at the distance of about 22 miles, and the grounds from Thursley to Bagshot on the north, including the district of Farnham and the drainage grounds of Fleet Pond, and many other small lakes, or ponds, as they are generally styled in the neighbourhood. In such an extensive district there are, of course, many streams to be examined, many springs and bodies of stagnant water, as well as the small lakes, which are constantly filling and emptying themselves, keeping up a fresh supply of water. All these sources and deposits of water received from me such attention as seemed necessary and compatible with the conditions of time and circumstance. As it was not my province to find out a new supply of water for London, but merely to examine a plan proposed, it was not necessary that I should be acquainted with all the water around, or that I should be

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able to say that there was no drainage ground so near London with an equally good supply.

As hard water was found to flow towards London from the north, the south, and the west, it was my belief, and probably the general belief, that there was no chance of any other supply whatever, and Pangbourne seemed the nearest place from which it might be taken out of the Thames with impunity. But as Professor Clark has shown that the objections to hard water are sufficient to deter any town from the use of it, the river water of the whole district seemed at once to be put out of the question, and either a new supply was to be sought after, as that of the Surrey district, or artificial means were to be used for rendering the river water soft. The state of the water inquiry seemed then to be fairly represented in the question: Is there any mode of obtaining naturally soft water for London, or must we use river water which has had the hardness removed by artificial means? That a place should have been found hitherto unthought of among all the plans for supplying London is itself sufficiently remarkable, and deserves the greatest consideration, as it at once obviates all the difficulties connected with the use of hard water, and connected with the means of artificially softening water. In examining the grounds, therefore, I have been fully impressed with the importance of the subject, and have endeavoured to give as simple a view of the matter as possible. I know that many analyses ought to have been given, and perhaps some persons would like a complete analysis of all the specimens, but this I have not had the opportunity of doing.

I think that in examining water the most important points are to know its general sensible qualities, next its hardness, then the amount of organic and inorganic matter, with an assurance that this matter contains nothing deleterious. It may be necessary to remark that rain falling on chalk dissolves it, and renders the water hard; or if it falls on the soil containing chalk or gypsum, the same result is obtained. If it flows over land containing much organic matter, a solution of that also takes place, and thus water is continually exposed to agencies which render it impure, or which render the use of it expensive. This latter, the formation of hard water, is the case in most if not in all the low lands of England, and there is often connected with it a considerable amount of organic impurity according to the drainage of the country. In the hilly parts of Wales and north of England the water is generally soft, and in some places more or less rendered impure by the organic matter of peat. The peaty matter on the hills of Lancashire varies from a few inches to a few feet in thickness; over a large portion of the district it is some feet thick. The silicious rocks give water of the purest kind, as the silica is very little soluble, and if there are any means at the same time of preventing the solution of organic matter, or of removing it when dissolved, water from the silicious rocks is the best that can be procured. The district proposed in Surrey is formed almost entirely of sand, shingle, and flints, forming a silicious stratum on which to collect the water. This stratum is covered in most places by a slight covering of peat. I went to the place first of all at the beginning of April 1850, the weather had been a little wet previously, but was fine for a part of the time, becoming wet for two days again, and again becoming

fine, so that I had an opportunity of seeing the ground under various aspects. Dr. Robert
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As it is on account of the softness especially that a silicious district is preferred to a chalk one, I shall first put down the degrees of hardness of the Surrey grounds. It is a common opinion that soft water is entirely unfit for domestic purposes, except in the matter of washing, this arises from the habit of collecting rain water from the roofs of houses and elsewhere into barrels or very imperfect cisterns, where it is kept until wanted. Water of this kind generally goes by the name of soft water, as if it were the only soft water, whereas water of the greatest purity and brilliancy from the rocks will be found even softer, although, from its appearance, it would probably, by many persons, be considered hard. This common opinion is not surprising, as water which flows for a long time under ground or flows to great depths generally contracts hardness and brilliancy at the same time, and water from the chalk districts coming through such strata as remove the chalk thoroughly has a very remarkable brilliancy. Beauty and hardness have therefore become connected, and at the same time there has been a notion that softness and vapidness are intimate. Professor Clark has shown that these qualities stand in no relation to each other.

There is a district in Surrey with water from 2 to 3 degrees of hardness, and another with water about 6 degrees; there is besides that, the river Wey and also an occasional brook which rise to hardness.

	Degrees of Hardness.
Frimley, opposite Frimley House	2·7
Military College	1·8
Bagshot Village	2·25
Between Bagshot and Chobham Hill	1·5
Parallel with the road, Chobham-lane	3·6
Bourne Brook, near Bisley	5·4
Canal, south of Bisley	4·6
Bisley Brook	5·4
Henley Park	3·1
Mitchet Pool	5·6
Wharf Pond	5·1
Pirbright Brook	6·
Standward Farm	5·1
Fleet Pond	5·5
Aldershot Heath	1·
Beacon Point	2·7
Spring in the Farnborough-road	5·5
Cove Brook	3·7
Well, above Wrecklesham	4·8
Brook on Holt Common	2·3
Holt Pond	3·7
West of the Narrow	7·8
East of the Narrow	2·8
Wey at Kingsley	13·5
——— New Inn below Kingsley	9·3
——— Frensham	5·8
——— Farnham	14·6

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	Degrees of Hardness.
Wey at Tilford	6·7
Stream pond at Wishange Down	7·7
? Well at Frensham	7·3
? Stream at Fox	4·75
? Spring in the hill above Fox	9·3
? Stream in the Tilford and Farnham-road	5·75
Frensham Large Pond	5·45
———— Little Pond	8·5
Abbot's Pond	5·25
? Redhill Brook, Farnham Common	6·9
1st Redhill Green	7·3
2nd —————	8·7

Perhaps it would be satisfactory, as a means of comparing this with the northern supplies, to take some just as they occur in my note-book, so that any comparison may not rest merely on an opinion of mine.

Hardness of Waters in Lancashire, and part of Yorkshire, Derbyshire, and Cheshire.

	Degrees of Hardness.
Blackstone Edge, large reservoir, near the high road	1·5
Canal below Littleborough	1·8
Brook flowing to Walsden	0·61
Nearest reservoir on Blackstone	2·5
Longendale specimens	0·9
Comb's Reservoir	4·9
Todd's Brook Reservoir	2·4
Ashton Canal	9·7
Woodhead, above the tunnel	1·8
Etheran, at Hadfield	2·27
Spring in the rock at Glossop (Catholic chapel)	3·2
Peak Forest Canal at Whally	4·7
Whally Large Stream	3·7
Rossendale Brook, Macclesfield	3·5
Macclesfield Canal	7·66
Wash at Hockham Brook	1·3
Peak Forest Canal, at Bagworth	6·3
Todd's Brook Reservoir at another time	1·85
Comb's Reservoir	1·9
Feeder from Bosley Reservoir at the bridge	3·9
Shell Brook	2·8
Todd's Brook at the Gauge	2·2
Comb's Brook, the feeder	3·4
Tunnel water at Woodhead	7·5
Armfield	1·1
DARWEN WATERS:—	
Earusdale Brook	3·
Jack's Key Reservoir	2·3
High Lumb Brook	1·5
Whitehall Brook	1·75

	Degrees of Hardness.	Dr. Robert Angus Smith.
Bayfold Brook	2.2	
Halley's Brook	1.75	
BOLTON:—		
Water at Nabs	1.36	
Reservoir at Turton	2.27	
Stream at Greenarms, Bolton-road	4.2	
BURNLEY:—		
Hunston	3.7	
Monkhill	1.25	
Clough Croft	2.	
Sweetwell	3.5	
Swinden	8.	
Thurs	2.7	
Well at Meadows	12.	
Water Company in 1846	6.5	

These are the softer districts, of course in the low grounds the water rises to 8, 12, and 16 about Manchester and Liverpool.

A well at Rainhill was	23.
Stagnant water in the sandstone	8.
Drainage from cultivated land	12.5
Water at Sevenshulme	8.4
,, Stretford	15.5
,, ,, at another part	11.2

The variations then are very great in all large extents of country, and this variation may begin very suddenly. The only way seems to be to pick out a certain district having the desired qualities, and fix its boundary according to the limits of the geological formation. We see from the above table that there is exceedingly soft water on the drainage ground around the Military College, Sandhurst, on Chobham Ridge, on Hungary Hill and Beacon Point, on to Aldershot Heath, all the drainage ground of Covebrook, and most, if not all, of the drainage ground of Fleetpond, Leith Hill, and Hurtwood Common, and the district from Elstead to Godalming, whilst on all the rest of the district the average seems from 5 to 6 degrees, which may also be called soft water.

It might be well to inquire here what the cause of these degrees of hardness really is. Water falling on a pure sand can only take up silica; in all the instances, however, there is a certain quantity of lime found, however small in some cases. This lime comes from the sand, which therefore is not a pure silica, as indeed sand seldom is, but it contains very little lime.

I allowed water of 10 degrees of hardness to stand in contact with an excess of the lower sand of the Frensham district, that is, sand about a foot below the surface; after 24 hours it had risen only about a quarter of a degree of hardness.

At the same time water of the same kind was allowed to stand in contact with the white sand of the surface, containing within it peaty matter, and it rose in 24 hours to 6 degrees, higher by a quarter of a degree than the pond.

The water which is supplied to Farnham comes through the sand at

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a depth of several feet, and is still soft and pure. Some of the finest water of the district was got at Beacon Point after passing through the sand to some depth and coming out as a spring, so that I am disposed to think that where there is hardness the nature of the surface merely, rather than of the sand generally, has a great deal to do with it.

This, then, is the great point in the district, that the water runs through sand, which can give it very little hardness in any portion of the district and in many parts only 1 to 2 degrees.

The total amount of inorganic matter contained in a gallon of the waters is as follows :—

	Grains.
Frensham Large Pond	7·25
Fleet Pond	9·12
Beacon Point Streams	2·76
Aldershot Heath	1·88
Cove Brook	6·08
Frensham Little Pond	8·88
Abbot's Pond	6·48
Henley Park	4·8
Frimley Brook	5·36
Mitchel Pond	5·72
Redhill Brook, Farnham Common	9·64
Rye Hill Common	2·96

Fleet Pond may be taken as a specimen of the water from one of the softest districts, which, however, in its flow, has become considerably harder than the springs on the hills, containing the same ingredients :—

	Grains.
Sulphate of lime	5·148
Carbonate of lime	1·80
Silica	·25
Sulphate of magnesia	1·43
Sulphate of potash	·094
Chloride of sodium	·132
	8·854

Also a little carbonate of soda, and a trace of iron scarcely perceptible to the taste. It is very probable that by evaporating larger quantities, and making a minute examination other salts would also have been found in minute quantities. In the Frensham Pond, there is in addition to the usual salts, such as sulphate of lime, carbonate of lime, and chloride of sodium, also chloride of calcium. It must be a matter of very little importance what is the nature of the salts when they are so low as 2 or 3 grains to a gallon.

A small amount of alkaline salts is a very important point in relation to the taste of water; in many parts the whole inorganic matter, both lime and alkaline salts, do not amount to more than between two and three grains, whilst the artesian well water contains above 60 grains. This causes the water at Trafalgar-square to taste exceedingly soft, or rather oily and mawkish, somewhat like soda water which has been boiled and lost all its gas, retaining the alkaline salts, which have a great power of rendering water vapid. The Thames water taken high up the river has also the advantage in an eminent degree of

having few soluble salts, but if taken down the river the salts injure the water, however purified by filtration or precipitation. I believe this is a prominent reason why the Chelsea water, which is supplied to houses frequently very clear, is still to water drinkers by no means agreeable. It contains besides the salts which contribute to hardness, 8·5 grains per gallon of inorganic matter, whilst the pure water at the beginning of the Thames contains none whatever. At London Bridge there is an excess in the water of 17 grains per gallon not contributing to the hardness, but rendering it vapid, however much filtered and however brilliant in appearance.

The presence of iron in water is a great objection, I am not aware of any reasons for the objection to a small quantity, except those reasons derived from taste and sight. When it exists as it does in the state of protoxide dissolved by carbonic acid, the taste is such as to make it unpleasant. When this taste is removed by the precipitation of the iron in the form of peroxide, the colour is a sufficient objection, the water is brownish or it loses its brilliancy; if time is allowed a brown deposit is formed. The water of that portion of the district from Farborough to Chobham, has a distinct taste of iron, or of a combination of peat and iron, in some places one and in some the other. I had said to Dr. Playfair that I believed the district to be very limited where water was found having iron in it; I have since found, however, that a slight taste is also found in several parts of the grounds which must be attributed to the same cause. That at Bagshot is very distinct. The absolute quantity found is not great; the quantity in one brook where the taste seemed as strong as in any part was only 0·11 grains per gallon. To ascertain the taste of iron in water I tried a few experiments with sulphate of iron, and found that an amount equal to—

·16	grains of sulphate of iron in a gallon	=	·0414 of the protoxide could be tasted.
·32	„ „ „ „	=	·0828 of the protoxide was very distinct.
·64	„ „ „ „	=	·1656 of the protoxide was very disagreeable.

Lest there should be any difficulty as to the use of the palate as a test, I tried the same with sulphuret of ammonia, and was surprised at the similarity of the results, the colour being distinct at the same strength at which the taste became distinct. With ·0414 of the protoxide there is a scarcely perceptible brownness in the water; with ·0828 there is a more decided brownness; and with ·16 there is a brownness which may be seen without seeking any peculiar position of the light.

The water from Henley Park deposited ·144 of protoxide of iron in the state of peroxide of course; after this it was quite free from any peculiar taste, and was excellent water. This iron was not free; when sulphuret of ammonia acted on it, it was not instantly blackened. The amount of taste, therefore, was not equal to the solution of the same amount by itself, some iron being united with the vegetable matter. There was a good deal of peaty organic matter with it, both had fallen down together, and both are kept in suspension by the same cause.

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From whatever source this iron comes, and whatever be its disadvantages, which need not be underrated, they are removed by the proper filtrations.

In examining water one of the most important points to ascertain is the amount of organic matter contained in it. The quantity should not be perceptible to any of the senses, nor should it be susceptible of putrefaction or capable of forming animalcules. Organic matter, like inorganic, may be either in solution or out of solution, a very small quantity in suspension deprives the water of its brilliancy; it is often found in this state in the surface drainage of land. If the organic matter be in solution it is important to know first of all what kind of matter it is. The word organic has such an extensive range of signification that it really conveys to us no very real knowledge when applied in this way. Sugar or oxalic acid would both be treated as organic matter, but neither would cause putrefactive decomposition, or the formation of animalcules. Creasote, essential oils, and many other substances would be treated as organic matter whilst they are opposed to decomposition, and although they are not to be found in waters such as we speak of, there is still a substance not unlike them in its properties—the acid of peat, which is acknowledged to be antiseptic, and which does not resolve itself into living forms. Peaty matter is therefore not to be confounded with the highly organizable matter found in river water which has passed towns. Even far up the Thames, where the water is exceedingly brilliant, a green deposit will be found of minute vegetable and animal life. The organic matter of the Thames at London falls down after a time in the form of a very dirty brown slimy mass, with perhaps a little green in it. The first deposit seems enormous, and one feels surprised how it could have come from a bottle which at first appeared to have nothing in it but water somewhat muddy. If this water be filtered through paper so as to appear perfectly clean, and again bottled up, it soon makes another deposit not so filthy in appearance, greener, and more like vegetation; the sides of the vessel are also covered over with patches of animalcules, and the bottle becomes darkened. If it be filtered again, the action will still go on, until nearly all the organic matter is worked up, at least all the organizable.

I said in one paper that I had got what I believed to be albuminous matter, or at least proteine, in the Thames water, and Dr. Hassall has found animal fibre; this would at once account for the rapid formation of animalcules did we not know already that the organic matter of the Thames comes from a source which must render putrefaction exceedingly easy.

A solution of peat however, acid or alkaline, will keep, as far as I know, any length of time without alteration. There are varieties of peaty matter also of which it is unnecessary to speak; some deposit more green matter than others, but generally a very small quantity, and the peat itself cannot form animalcules. We may know indeed from the composition of the matter in water whether animalcules may be formed; they seem to have the same chemical composition as animals, live on the same nitrogenous substances, and are subject to very much the same laws. Spallanzani says, “Too much heat destroys animal life, and animalcula die about the same degree of heat (as leeches, worms, and tadpoles), 106° , 108° , or 111° .

“All animalcula are not alike affected by cold. Some die at freezing, or a degree not much greater, others survive at 10 degrees. The odours and liquids that are a virulent poison to insects, are the same to animalcula. Such is the odour of camphor, the fumes of turpentine, sulphur, and tobacco; oleaginous, spirituous, and saline liquids are equally destructive. The electric spark is a thunderbolt to both. Agents slowly destructive of infusion animalcula are likewise fatal to insects, such as the vacuum of an air-pump.”

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As these great objections to Thames water are, in fact, like animals, and live on what other animals live, we shall get rid of them entirely by using water from a district where there is no food for them, or water which contains only peaty matter, which does not feed them. In saying this, I do not mean to say that there are no animalcules to be found in the district in question; I saw a pond on the heath with abundance, but the water which I have had has deposited as few as any water from any district can be expected to do. There is a kind of popular fallacy in connexion with animalcules, arising out of some notions once prevalent and now not entirely exploded, that there is no place without life in it, and that the elements themselves may be formed of active living points. But as far as good water is concerned, there is no necessity for any such theory; no microscope can see anything in it, and no one, not even a Brahmin, need be afraid that he is drinking living creatures. There ought to be none at all in our food or in our drink, and one of the most important things is to have water in which there is nothing liable to form them.

There seems to be no very satisfactory way of getting at the amount of organic matter when it is in very small quantities in water, at least a theoretical perfection is wanting in the process, but a practical perfection is easily attained by simply boiling down the water, drying the residue, and burning the result. The uniformity of results got in this way is such as cannot be surpassed. The quantity is too small generally to make it possible to make an organic analysis with oxide of copper in the ordinary way, and the result got in that way would be of no advantage to us. It is sufficient to get the quantity by burning off, and to get the quality by seeing the results after keeping it for a sufficient length of time. The peaty matter got in this way is the following:—

	Grains in a gallon.
Frensham Large Pond	·7
Fleet Pond	1·32
Wharf Pond	2·36
Beacon Point Springs	·76
Cove Brook	·36
Frensham Little Pond	1·76
Abbot's Pond	1·68
Henley Park	3·32
Frimley	2·24
Mitchel Pond	1·68
Redhill Brook, Farnham Common	2·86
Way at Frensham	2·44
Stream at Bagshot	6·20

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I mentioned to Dr. Playfair that three grains was the highest; it appears that there is an exception here. It is clear, however, that there is very little. I may mention that all the waters have stood a sufficient time to form any deposit that might be likely to take place; some collected in warm weather in May and some in April.

As, I believe, these are the chief points about the water, the softness, the amount of matter in the water, the amount of organic matter, and the nature of the organic matter, it is only now necessary that I should speak of any difficulties rising out of any of these points. Mud-diness or opacity of any kind will not require to be dealt with, the water seems all clear, indeed it is almost proverbial that water in sand is always clear. This is, no doubt, partly owing to the fact that water which is not clear would soon deposit so much of what it has in suspension as to cover the sand which forms the bed; if sand is seen clear at the bottom, and if it keeps clear constantly, it may be a proof rather that the water comes to it clear. If, however, water falls on sand, the particles are too heavy to allow of their being kept in suspension, and the water passes off clear. If it falls upon sand mixed with clay, or with fine particles liable to be kept in suspension, it soon washes them out, and the water on the free sand becomes again clear.

But the other reason that sand actually clears water is one which deserves the most attention, and all the filters in the country are a sufficient proof of the fact. If a stratum of soil through which water passes in a muddy state be put on a stratum of sand, and the water passed slowly through, the soil is not carried through the sand, but the water passes through perfectly clear. The water passing slowly through soil alone, at a sufficient depth, comes out of drains perfectly clear.

The Bagshot waters are known to contain iron to some extent, as Dr. Playfair has mentioned; but it is not always the case even with the surface water. Taking the whole extent of the district under examination, it is not common to taste iron. This metal can only be objected to when it is in a sufficient quantity to affect the taste. This occurs in what is properly called the Bagshot portion of the district. The iron cannot always be detected by the taste, because, I believe, it is united with a peaty acid, and the taste of both is in many cases very peculiar. The conjunction of the peat and the iron shows that the water obtains this taste at the surface, and that it is surface-water which tastes in this way. It is only in some places where there is any colour, the quantity being really very small, but as it can be tasted, it must of course be remedied if possible. If we follow any of these brooks downwards, we find that there is a continually brownish deposit going forwards, and the taste gradually disappears. The united peaty matter and iron are probably kept in solution by the same cause which keeps protoxide of iron in solution, and when the carbonic acid is dissipated, or when the iron becomes oxidized, the peroxide falls down. This is then a lesson as to the mode of purifying the water.

It has been said also that the sand absorbs a great deal of water, and that it afterwards comes out in various places according as it meets with impervious strata forming numerous ponds. If this be so, the ponds will consist of water which has come through a considerable extent of sand, of underdrain water in fact, and this will account for the

water in these cases having less of any peculiar taste. I think it might be shown that wherever there is any taste of peat or of iron it is from surface-water. Dr. Robert
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The best proof of this will be found in the following instances. A stream at Redburn Green had a bad taste from the above causes, another stream running parallel, and about a hundred yards from it, was very pleasant to drink. This second one was traced up to springs issuing from the sand on the side of the hill.

At Beacon Point, the water which runs through the sand is not only pure in colour and taste, but also in softness. On Hungary Hill and the neighbourhood there are numerous instances, and it seems a general rule. On Chobham ridge also the water which has a colour and taste, is taken down to the sand, and issues again from a hill, where it is clear and pure. The under-drainage of the district is known therefore to give pure water, and as a supply for any town would, in all the cases seen by me, be very desirable.

The power of sand to purify water is really very great; I tried a few experiments upon it which I may as well mention. A strong alkaline solution of peat was made and passed through sand, the water came through clear, retaining only a taste of the earthy portion of the sand. The solution was strong enough to show colour through the twentieth part of an inch. Adding acetic acid to this ammoniacal solution until it becomes acid, gives an acid solution of peat; it is precipitated by some acids. This solution came through the sand equally clear. In both instances the matter was in perfect solution. As the action does not refer either to acids or alkalies, it seems probable that there is here an action independent of the ordinary chemical affinities, but as far as the purifying of water is concerned, it is enough to know that it is a fact. Pounded bricks acted equally well, also oxide of iron and oxide of manganese. Indeed every chemist must have perceived how beautifully some precipitates may be washed, and how pure the filtrate is which comes from them without any especial attention; amongst these oxide of iron and alumina are conspicuous, whilst others require many precautions and several are entirely unmanageable, that is, they cannot be washed with pure water at all.

It would not be correct to say that sand is the most powerful filterer in proportion to its bulk, it is too coarse generally to act except when there are large quantities, and other substances purify the water, using much smaller quantities. It is however so general, and it is used in nature for purifying water so frequently, that it deserves most attention. The sand requires to be of considerable thickness, at least so that the water does not run too fast off, but at the same time nearly all the impurities removed will be found on the surface of the filter. In order to try the effects of filtration, I used strong sulphuric acid in which pieces of wood had been soaked, so that it was exceedingly black, thinking by the strength of the acid to overcome all action which a filter might have but the acid came through very pure, and left the upper part of the filter with a dark film, where all the colouring matter had been deposited. The same was tried with muriatic acid, which had been rendered impure by some vegetable matter, and which did not deposit by any amount of mere standing. The acid came through brilliant. The filtration of acid liquids in this way is an old process; it is given in an early edition of

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Ure's Dictionary of Chemistry, where pounded glass is recommended ; but I do not think it has been used for matter in solution.

Percolation through a porous stratum is capable, in fact, of removing any amount of organic impurities from water, as the universal admiration of spring water sufficiently shows, and this removal of the organic matter which is an objection to surface-water, has generally been considered a sufficient compensation for the inorganic matter and hardness which it has acquired in the process, by going down to great depths and remaining a long time. It is true, that to remove the last traces of organic matter, seems to require that the percolation be continued a considerable length of time or space ; it happens here as in other cases, that the purity is according to the extent of the process of purification.

It may seem, however, that the very word *crenic* acid is a proof that wells have organic matter in them of necessity ; *crenic* implying that it has its source in wells, but they differ very much among themselves, from the impure well badly filtered, to the pure well with scarce a trace of organic matter to be found. There are cases in which organic matter comes from under the surface, but they are not legitimate exceptions. Sometimes there is a stream of water instead of a percolation, there are cases where vegetation has come up, and even fishes ; many cases of bitumen and naphtha, which are also organic substances, not coming within the scope of our subject.

I shall describe the state of the heath as far as relates to natural means for purifying the water. The district is covered by sand or by shingle if it may so be called. This sand is of a reddish brown, and in some places has a considerable depth. On the surface is heath. The upper layer forming the soil of the heath is composed of peaty matter and sand ; the peaty matter gives the blackness. When the peat is washed away, the sand is found to be of a pure white. In many cases where the plants have been removed, and the rain has begun to wash away the fine peat, leaving the white sand, the mixture of the two gives a peculiar colour to the ground, a grey with a tinge of purple in the distance. Sometimes the peat is found entirely removed, and then the sand or flints are found perfectly white, shining on the surface. The reddish sand lies immediately under it, and this effect has been produced merely by taking off a few inches, a mere scraping from the surface. The sand of the surface mixed with the peat is evidently washed white by the acid of the peat, and it is remarkable how decided this line of white and red is over the district. The soil is such a good filter that none of the acid goes much below the surface, so that there is no white sand to be found above a few inches deep, generally, as far as I saw, about eight inches ; although there were cases where it was not so deep, and also cases where it was two feet deep. As the upper sand must retain water having matter in solution to cause this whiteness, so the under sand not being acted on, it must be penetrated by water having no such matter in solution. It follows that the peaty matter must get filtered out of the water before it passes from the upper layer to the under layer. It is then an interesting fact that at the junction there is a blackness, a black line in fact running along under the surface, having white sand above and red sand below, it is in fact the line of filtration. It is an old remark that humus acts as a charcoal filter ;

although its action here, except as a strainer, is difficult to understand, the soil does seem to be formed of a mixed charcoal and sand filter which does its work very effectively all over the district. Dr. Robert
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The sand above is found to be saturated with water, while the lower sand, not more than a couple of inches from it, is only damp; showing that the water passes through very slowly, and so has time to undergo the process of filtration, which is not a mere straining through a sieve, but an act of purification. The black line, which is an accumulation of carbonaceous matter, is a considerable hindrance to the passage of the water. This will perhaps account for the great part of the water in the streams, at least in the Bagshot district, being surface-water, as the water will have a greater facility for moving forward above the line of filtration. If the water in the ponds is in many cases water which has passed through the soil, and been thrown up by impervious formations, it will account for the greater freedom from a peaty taste, and also for a greater hardness than is found in the streams.

It might be asked if this filtering removes the iron, and the answer is already to be found in the wells and springs; if the iron is in combination, as I believe it is in most cases, with peaty matter, they will be removed together. At any rate they are both removed. Professor Way has removed many inorganic salts by clay and soil, and shown that they are absorbed by clay, especially in great abundance.

But to obtain these results, the water must be allowed to pass through the upper stratum, and thus the filter, instead of occupying only a few acres, straining the water from its grosser impurities, will be a thorough natural purifier, where the water will be elaborately cleansed by the ordinary natural processes which form the best spring-water. The water in that case will not be allowed to stand so long on the surface, and become impure in contact with the surface; this will prevent evaporation such as occurs in some parts of the district where there is stagnant water, it will also prevent the necessity of extensive artificial filtration, which the use of this natural filter will to a great extent, if not entirely, supersede. As to whether it will be in some measure lost in passing through the sand, this is a point which does not come under my experience. I wish to show, as I had occasion in a former paper to say, that when such impurities are to be removed, "soil is the largest natural disinfectant, and, in conjunction with air and water, is the most efficient of all, especially if the land be drained." And as soil removes organic matter from solutions, it removes also, at a certain depth, what the water has received in contact with the organic matter of the soil itself. If the processes at Hungary Hill, Leith Hill, &c., are copied, a great portion of the water when collected will be equal to what is obtained there at present; in which case a better product can scarcely be desired, and very few places can furnish an equal supply. It will, of course, be much superior to what Manchester is now receiving, and it will be equal to a great part of the district from which it will receive water.

It must be left to experiment to settle whether the turf should be pared, in order to improve the water, or if this would cause a loss of water. I do not know the quantity, but in many parts there is certainly a great lack of streams. If the water flows into the ponds by any under-ground channel, this lack of streams is a great advantage; if it is lost, it is a disadvantage, of course. As it appears from the quality of

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the streams, that the water is chiefly surface water, the lack of streams in some parts may be due to the rapid surface draining of the ground, which again becomes an advantage, increasing the facilities for collecting.

The great object, however, of going to this district, as far as I know, is to find soft water; the actual quantity of hard water could be supplied to London from several sources. The greatest hardness here is about six degrees; there is little water above that point. The application of artificial means to soften the water from hard-water rivers could not, I believe, bring it lower than this. We have then here prepared what would otherwise require artificial preparation if the water were taken from the Thames. The mode of purifying by lime, which is Professor Clark's process, has been tried frequently, and always with advantage, but then never in such enormous quantities as London will want. The lime removes the excess of lime in the water, where it exists as carbonate, and the organic matter also is taken down, leaving the water as clear as can be wished. Indeed, the water from lime districts is often remarkably clear; nothing can be wanted finer than the Thames at its sources as far as this quality is concerned. The wells of chalk districts are sometimes very strikingly superior to those of the neighbouring districts, and possess a brilliancy not easily attained otherwise. It is astonishing what an amount of matter of every kind is removed by the lime; the fine particles which cannot be seen, but only cause a dulness in water, are rapidly dragged down with it, and stray vegetation, animalcules, and filaments of various kinds, are rapidly made to sink.

Professor Clark has shown that there is very little, if any, excess of carbonic acid in river-water, and that the water would therefore not lose any of its carbonated nature by his process. There is an excess, however, of carbonic acid in well-water, and sometimes to a considerable extent. The same will probably be the case in water well filtered through a sandy soil, which will in fact be well-water, or, as we may call it, artificial spring water. This term was used by Marshall to designate rain-water which had been passed through a bed of sand, and made more palatable—a mode which he recommended to farmers as valuable for cattle, being both agreeable to the taste, and more wholesome than hard waters. There will be an advantage in favour of the natural process without the lime.

As far as air is concerned, river-water will probably contain much the same quantity, or at least not less after liming than before. A quantity was tried, by raising the temperature of the water slowly, until bubbles of air appeared on the sides of the vessel and bulb of the thermometer; these were generally very distinct at about 70° in both specimens. A very good mode of very readily trying the aeration of water, as far as oxygen is concerned, is the use of sulphate of the protoxide of iron. This salt oxidizes very rapidly, and leaves a deposit of peroxide of iron in a yellowish state. If water is boiled previously it does not oxidize, but remains perfectly clear. A little practice with this mode of testing will give a very clear idea of the amount of oxidation of water. If the weight is required accurately, it is, of course, subject to an error. When water is thoroughly deprived of its oxygen in this way, protoxide of iron may be precipitated in it of a pure white; this protoxide, if put

at the bottom of a vessel of water deprived of oxygen, will show how rapidly the water absorbs it. In 10 minutes a change will be found to take place.

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However valuable the process of Dr. Clark may be, all will allow that, if it can be left out without loss, it will be an advantage to do so. The advantage of using a natural supply, instead of one requiring preparation, must always be great; the labour of the manufacture, and the risk of mistakes, being reasons enough. I have no wish to speak against Professor Clark's process, having seen several remarkable instances of its value. I must be excused, however, for preferring simplicity when it can be got. This and some other questions might readily be answered by experiments which private individuals cannot make.

For the same reason, it will be important that water should be put into reservoirs in a state of purity, and it will not require any after-purification, or at least very little. Water which is perfectly pure cannot corrupt. The water which does cause the growth of great numbers of animalcules and much vegetation cannot be in a pure state, and the formation of these bodies is a removal of the evil by making the impure matter insoluble. Well-water or spring-water, passed through inorganic strata for a sufficient length to destroy the organic matter does not trouble us by growths of any kind; river-water, coming over the surface of the ground, does, however, often cause immense masses of vegetation. The same clearness is preserved when water has peaty matter only in it. There is no vegetation, or very little. Sometimes the stones remain clear for years; there are cases, however, of green matter forming, probably when the peat is mixed with other vegetation, which affords materials for the growth of new forms. Water bubbling from underground may be kept in the dark in a stoppered bottle without change; but river-water, or water having organizable matter in it, will not keep so. It will form vegetation first, at least in the light, and afterwards, if the same vegetation be kept in it, it becomes putrid, dissolves to some extent in the water, and becomes very nauseous both to the taste and smell. If it is kept in the dark, it becomes putrid also, without the formation of the vegetation previously. This is the result of keeping waters in bottles; it will not perhaps be possible to apply all this to reservoirs, as the quantity will be great, and the change frequent. If impure water is put into a dark reservoir, it would, no doubt, be retarded in its deposit either of living or dead matter, and the deposit would be probably longer in forming than in a vessel kept in a house. A dark reservoir would therefore be of advantage in preventing any impurity in the water from coming to light in the form of vegetation, of animalcules, or black slimy deposit.

The question might then be asked, what would be the result of keeping pure water in an open reservoir, or water as free from organic matter as that of which we speak? The answer would be best got from the ponds themselves; and there, in such cases as those where the water cannot reach the pond without passing through much soil, the water lies on the cleanest sand, as at Frensham. I do not see why the water may not all be so managed; but, at any rate, the amount of impurity got from the atmosphere, except in the neighbourhood of a town, cannot be more than the passage of the water through a filter before delivery could abundantly clean.

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What I wish more particularly to say is, that the presence of life is not the only index of the impurity of water, although it is an important one; and that it is not enough to prevent any living creatures from appearing, by using dark chambers and a low temperature; that the water must not have in it the matter capable of forming these creatures, and then the place is not so much a matter of consequence; all that is wanted is, that there be no source of impurity which can reach it.

We are not surprised that water from ploughed land, pure as far as clearness goes, but containing four grains of organic matter to the gallon, which matter, when burned, has a strong nitrogenous smell, should, in the course of six months, form a deposit in a reservoir of considerable thickness; and, on the other side, it can give us no surprise when a reservoir, having only peaty water in it from the Bolton or Pike district, should have no appearance in it whatever of vegetation. In one there is the material, and in the other it is wanting. The mode of keeping water pure in dark places is applicable, therefore, to all water which has organic matter in solution, but not essential to pure water: it is, in fact, a mode of preventing the impurity from taking a nauseous form, and also of getting into a more deleterious state.

From the manner in which I find this paper has been written, it will be better that I should give a short abstract of what I believe true on the subject.

The Surrey district is composed of sand and shingle, with a thin covering of heath.

The water from it is soft, varying from 1 degree to 6 degrees, the average being probably about 4 degrees of hardness.

The nature of the surface renders it exceedingly fitted for natural filtering or purification by drainage through the substratum. This is the mode in which the purest waters are obtained, and by which the purest waters are got from peaty districts.

This mode of slow filtering removes all organic matter from solution, so that the organic matter on the surface is a matter of less importance, as it is remedied by drainage.

This is the method by which spring-water is prepared, and by which it is aerated, or supplied with carbonic acid and oxygen.

This water might be supplied to towns without filtering, unless by some unforeseen circumstances it might be somewhat diminished in brilliancy during its flow.

This has an advantage over the river-water in softness and in absence of organic matter, which qualities must be produced by artificial means when river-water is used. The comparison in expense and practicability must be a matter for further investigation.

This mode of filtering removes iron in the state in which it is found in parts of the district.

As far as surface is concerned, the district in Surrey is peculiarly fitted for this mode of purifying water.

Water so purified could become nowhere putrid, from want of the material which putrefies. Peaty matter itself does not putrefy; even if it were not removed, there would be very little organizable matter, much less than in the neighbouring rivers.

Reservoirs with water thoroughly purified would not become filled with vegetation in the light or in the dark. To prevent water from

putrefying, presupposes putrid matter. Water should not be supplied with such matter in it. Dr. Robert
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As little rain as possible ought to fall into reservoirs, unless, perhaps, many miles from towns, the impurity in the rain even outside of towns being great.

It may be objected that water so pure as this cannot be got; and this brings us to another reason, the reason which seems to me most in favour of covered reservoirs arising from the impurity of rain got from the neighbourhood of towns. This impurity must be very great near London, and probably several miles from London. I have just been collecting water from the fields a mile from Manchester, and about two miles from any large chimney; it is very impure, and of a bad taste; it could not be used as a supply for a town without careful filtration. I reserve the description for another occasion. It would be an important thing to know at what distance from London it would be safe to leave reservoirs uncovered, and whether at any distance whatever a large amount of rain-water would be an injury. It would probably be refining too much to speak of any injury to distant reservoirs from rain; but as to supply reservoirs in the neighbourhood of the town, it would not at all be an over refining, as the amount of impurity is very decided. If the water could be got so pure as not to require filtering, then reservoirs at the town would not be wanted, or at least diminished to a very small size. If it should be found that filtering cannot be dispensed with, the removal of filters far into the country will, I believe, be an improvement, as in that case they will get the water in a clearer state, and have less duty imposed upon them.

Plan of Drainage.

I believe I have given as far as I have gone a correct account of the water district, the observation of drainage in many cases of this and other districts has suggested to me a few remarks which may be added, although perhaps not in conformity with the general scheme, the details of which I do not know. I believe it is essential to the district that it be drained, if possible, in every part of it, with more or less care. It is perhaps too much to expect that this will render the use of filters unnecessary but it is not too much to expect that fewer would be wanted, as a little straining would probably be all that would be wanted at certain times. The water might be collected in the same way that water is now collected by streams and rivers. The mountain streams seldom bring down any mud, but are generally clear. These streams are purified by natural filtration, sometimes from great impurities. The water at the top of a hill may be quite brown, but this is no indication of the colour of the same water at the bottom of the hill. The water on the top is brown very frequently from lying for a long time on the moss or heath, having at the same time a strong taste, quite unpalatable. When this goes a few hundred feet or yards down, it is clear and beautiful, having no taste. The manner in which this is performed is curious; it has often surprised persons, and I had an opportunity, a short time ago, of finding some water brown from its source in the peat, in the act of filtration. The

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water passed under the surface; the side of the hill on the upper part was wet, so that the feet sunk some depth in the moist soil, but although the water was flowing down the hill, the surface became dry and solid; the water, therefore, sunk down. On going further down the hill, the water came out again, so that the ground was wet. It flowed to some distance, and become lost afterwards in a gravelly part of the ground. Again the soil was dry, the water passed under, and emerged from the surface a few yards below, forming a well, which served for cattle. From this well it ran down into the stream at the bottom of the valley. In the course of an hour's walk on the Derbyshire hills, I met several cases where the stream entirely disappeared from its channel and came out below, pure. Cases not so distinct, that is, requiring more examination to trace them, are in abundance. Heath, then, may cause any amount of impurity in water: it is a matter of no consequence if there be only a purifying agent below. Water does not run over the surface merely when the ground is sufficiently porous. In this case the substratum was a white rock, broken into gravel and sand on the surface, and varying in its porosity from the manner probably in which it was broken. The manner in which the water ought to be collected from land, ought, in my opinion, to be similar to this. The arrangement of the surface might be made in such a way that the water could not flow from the hills without passing through a good deal of the lower strata. For example, if a ridge of gravel and sand were run along the side of a hill, the water would pass through that before it came to its outfall. In doing this it would be purified. In the same way also it might be necessary to prevent the water from flowing over the brink into streams before passing through its purifier. Wherever the water does undergo this process to a small extent, a little assistance would probably complete the effect. The water would be purified on the spot. Some hills resemble closely barrels of water; they are tapped below, and the water comes out, whilst the surface does not betray a great amount of water.

Any one may have observed that a mossy hill seems always wet, but it is a most difficult thing frequently to get any water from it. The water does not become perceptible till near the bottom of the hill, when it oozes out of subsurface cavities, or through peat, gravel, or sand, as it may happen to be. If it happens to come through the peat only, it will, in most cases, be more or less brown, but if it happens to go deeper it will be purified. In cases where it will not be sufficiently deep for purification, it may only be necessary to deepen the stream, and so prevent any water from coming into it, except from a great depth. This mode of flowing may be seen in the draining of mosses, where water is collected six feet or more under the surface, where it does not flow at all over the surface, but passes down immediately, and is collected below, so that it is possible to cause the water to pass through any required depth.

A great deal of the water of the district passes already through this ordeal, and becomes purer accordingly as it does so. The consequence of this is, in some places, that it gets harder, as around Wharf Pond and some others, but it is not always the consequence, as the deep springs in the hills show, and the water of Farnham.

I am not sufficiently acquainted with the geology and levelling of the district to know how this could in all places be done.

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1. You have examined the waters of most of the gathering grounds for the improved supplies of the Lancashire towns, have you not?—Yes; I was engaged for the examination of the Manchester new supplies, derived from gathering grounds, on the hills between Lancashire and Yorkshire; and also the proposed gathering grounds from hills to the north of Derbyshire, and some from Cheshire. I examined the gathering grounds for the supply of Bolton, and part of the gathering ground appropriated for the new supply of Liverpool, and also those for the supply of Burnley and other towns in Lancashire.

2. In those instances, the proposed gathering grounds were wastes and moors, were they not?—Always so.

3. Did you examine the supply proposed by Mr. Rawlinson to be brought in for Liverpool from the Bala Lake in North Wales?—Yes, I did.

4. In all these cases you went to the grounds yourself, and collected for yourself the specimens for analysis?—Yes, I did. I may observe that besides the grounds mentioned, I have examined the water from grounds in other districts, simply to determine some questions for myself, as to the effect of peat upon waters.

5. You completed practical analyses in the several cases for advising on improved supplies for the use of the population of the several towns?—Yes, I did.

6. We understand you to concur generally in the conclusions from evidence we have received, and which you have seen as to the superiority of soft water over hard for drinking, for culinary purposes, for washing, and for manufactures?—Yes, I do. The most earnest attention has been directed in Lancashire, however, to the importance of soft water for manufactures. The number of schemes which have been proposed for removing lime from boilers, or for removing it from the water, show the importance that manufacturers have attached to the subject.

7. You have now visited a number of waste lands, heaths, and moors in Surrey and Hampshire, which have been pointed out to your consideration as eligible gathering grounds for improved supplies of water for the metropolis, and have examined specimens of water from them?—Yes, I have been over these grounds nearly a fortnight, and I have examined about eighty specimens of the water. For two days I was accompanied by Professor Way.

8. Before entering into the particulars of your examination, will you state the character of the waters obtained, as compared with the water derived from other gathering grounds which you have examined; and, first, as to the Bala Lake; have you the analysis of that water?—Yes; it is the following:—

From the Dee at Llangollen.

Hardness	2·5
Carbonate of lime	2·1
Alkaline salts	·532
Salts left by the decomposition of the } organic matter }	·168
Organic matter	·28
Entirely peaty matter	

I had too little water for further particulars.

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9. You have examined the water as supplied to the town of Farnham?—Yes, I have.

10. Will not the Farnham water represent a fair specimen of the water derivable from a large extent of the proposed gathering grounds?—Yes, allowing the average of the Farnham water to be about two and a-half degrees, it will represent the quality of the water derivable from the whole of the eastern part, that is from 20 to 30 square miles of gathering ground, as far as I have seen, nearly all waste.

11. Will you give in the analysis which you have made of this water?—The specimen of Farnham water which I received was unfortunately taken from a place where impure matter from a garden was allowed to enter; I shall therefore give the analysis made by Professor Way—

	Grains in a gallon.
Silica	·55
Lime (as silicate?)	·375
Sulphate of lime	·280
Sulphate of magnesia	·557
Chloride of magnesium	·552
Chloride of sodium	1·440
Chloride of potassium	·354
Organic matter and water of com- bination	1·245
	5·323

So far I can corroborate this, that I found a spring on the same hill containing 2·76 grains of inorganic matter in a gallon, and ·76 of organic.

12. From the guagings taken at the end of six weeks' rain-fall, it is reported to us that the extent of supply derivable from these wastes which are distinguishable from the rest would be about 28 millions per diem, or equal to a daily supply of 100 gallons per house in the metropolis; will you state the general character of this water as compared with that of the Bala Lake?—I cannot speak to the quantities; but in respect to quality, the Farnham water is equal to the mass of any Lancashire or Cheshire water derived from gathering grounds which I have examined. In softness it is equal, in some places superior to the Bala-Lake water, from the proposed collecting point above Llangollen; it is also less coloured with peat than the water of that lake. There are portions of water derived from what is called the rough rock in Lancashire, nearly as perfect in every respect as distilled water; but the gross amount of the Farnham water would be equal to any other gross amount of soft-water supply for a time which I have examined, taken indiscriminately.

13. We are now speaking of the water as at present derived; but may it not be even further improved by care in its derivation or collection?—Yes, materially.

14. In what way?—By under drainage chiefly.

15. Will you describe the advantages you expect from under or shallow drainage?—My view is that most rain-waters will be improved by passing through an appropriate filter. My belief is that all water coming from rocks or sand is more brilliant than simple rain-water. All rain-water is apt to bring down with it vegetable or animal matter floating in the atmosphere.

16. Where have you made collections of rain-water?—In Manchester and the neighbourhood of Manchester.

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17. Then you probably give us an impression simply, and not the results of experience, as to rain-water falling in purely rural districts?—Yes, that is so; but still I should prefer the water which had passed through a filter, as purifying itself from the matter caught upon the surface, for some foreign matters are caught upon the surface of all gathering grounds which have yet been found, or are likely to be found, for town supplies.

18. Are you aware whether in any of the towns now supplied, or to be supplied, with soft water from gathering grounds, as at Bolton or Manchester, under drainage has yet been thought of?—No, none of them.

19. Even if the surface water were taken, as for the northern towns, from the surface of the district, crudely as at present, and without any further improvement, would not the general supply from the entire district you have examined be superior to most river-waters, not to speak of the Thames?—Yes, certainly. It would have the greatest superiority in respect to softness; it would have less mineral, and would be nearly pure from animal matter; and it would have less vegetable matter. The only matter in it is peat, and that is not visible to the eye. I except some portions of the district which might be separated or improved.

20. The whole district is supposed to be covered with sand; if so, what portion is covered with the same description of sand?—Speaking roughly, I saw 20 miles of land, and 30 miles of shingle and sand.

21. What are the chief causes of the variations in the quality of water which you find in this district?—Variations arising from peat chiefly.

22. Is not the peat very thinly spread over the whole district?—It is not thick anywhere; but the variations in the quality of the water are caused by the state and inclination of the surface, which occasions the rain to wash the peat surface alone before it is discharged into the brooks.

23. We understand, then, that by the shallow drainage which you contemplate, you have in view the instance of the derivation of the water for the supply of the town of Farnham, by which the water falling on the surface of peat, passes through the peat, and thence through the sand into the tile-drain, cleared of the peaty infusion?—Yes, that describes the process.

24. What is the depth of the peat on the gathering grounds for Manchester?—Some of it about six feet deep; a great part of it about four feet deep.

25. What was the depth of the peat on the gathering grounds for the new supply of water for Liverpool?—That which I saw was from two to three feet deep.

26. Mr. Donaldson, the agricultural surveyor, reports to the Board, that the surface peat on the Surrey wastes is so thin, much of it some six or eight inches thick, that it might be taken off at a cheap rate?—Yes; but from the instances which I observed, it would suffice to take off two or three inches of peat from the surface.

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27. You do not then think that the infusion of peat, even if the water were taken as it is, would be highly objectionable?—No, it is not thought so; peat itself is highly antiseptic; it is not considered favourable to the production of animalcules; it is not directly convertible into animal life like the organic matter in the Thames, and most river water. The only objections I know to it are the taste and the colour, which are disagreeable when the infusion is considerable.

28. Besides the instance of shallow drainage in this particular district, have you observed shallow-drainage waters in other districts?—Yes, in a few instances. I may mention one at Rochdale, where the surrounding waters went as high as 13 degrees of hardness; but the shallow-drainage water obtained from a ploughed field was about four degrees and a half. The comparative purity of the drainage water in other points was similar.

29. Will you state your own view of the powers of the surface stratum of land for depuration?—I passed a strong solution of peat through a filter of sand, and found it quite purified. I passed then an ammoniacal solution through the filter, such as is found in warm weather on the tops of hills on peat, and found it quite clear. Then an acid solution was passed through, which also was quite purified. Afterwards, I passed the same solution of peat as at first through various materials; oxide of iron, manganese, lime, and iron filings; all of which substances purified the peat. I then passed strong solutions of woody matter in mineral acids; these also became pure; sulphuric acid and muriatic acid, for example. The matter was left chiefly on the surface of the filter. I observed also that all the peaty districts have a black stratum a few inches deep, below which there seems to be no organic matter, or very little. A similar stratum, not coloured, may be observed on all soils, but rather deeper. Water taken above the point of filtration, that is, not having passed below this stratum, contains much organic matter; but below this line it is true drainage water, and is purified like water from a shallow spring. Leaving the cause for examination elsewhere, these facts lead to the conclusion that the power of filtration to remove colouring organic matter in solution is really enormous; but it must have time, as the action is not a mere straining through a sieve; the artificial filter is for this reason generally too small for the full effect obtained by the natural mode of filtration, where time is given for a complete act of purification.

30. Will you describe the general condition of the other remaining districts?—The Frensham district is entirely a loose sand, with very little peat, the water less soft by three degrees than the northern and eastern portions; but I think it might be had still softer if the district were drained faster—an experiment which I made showing me that what little lime it did dissolve was, in a great measure, if not entirely, caused on the surface. The districts of Hurtwood and Leithhill are covered with gorse, heath, and wood; and the water will, I believe, be found very soft under any mode of collection—that is, whether drained or not. I have founded my opinion of the water independently of the Bagshot eastern district, the water from which, as it at present flows, is too much coloured by peat, and so much so as to be disagreeable to the taste. I saw abundant reason to think, however, that by careful filtering in

its natural position it would be completely purified, and would then make a valuable gathering ground. In company with Professor Way I saw instances of purification in this manner, I have therefore only to speak of its capabilities as a gathering ground, but not of its present supply of water.

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31. Do you see your way of obtaining any supplies of equal purity for the metropolis?—I know of no other silicious district near London, and I take it for granted that there is none producing soft water, or geologists would have pointed it out. Any other natural soft supply, therefore, seems entirely beyond all expectation, and the only mode of obtaining any other supply of soft water would seem to be by artificial purification. As the process of purification could not by any means yet adopted bring it to a point softer than the district proposed, I see no inducement to try any hard-water supply, and to be at the trouble of artificially softening it; whilst, I may add, that the artificially softened water does not equal the natural supply, it is less aerated, and may be otherwise objected to.

32. Even if little or nothing were done either on the surface or with the mode of collection, we are to understand, then, that the supplies derivable from the greater portion of these Surrey sandy districts would be on an equality with the soft water supplies of the northern towns you know of, as at present, collected and distributed to them?—Yes, certainly.

Dr. ANGUS SMITH ON WATER-PIPES.

The use of iron seems essential for the conveyance of large bodies of water, the use of other materials may be better suited for smaller bodies. It is the most wholesome that can be used, although it has several disadvantages connected with it, arising from its tendency to oxidize on exposure to water having air in it. There is seldom carbonic acid in town waters sufficient to dissolve the iron, and to make a chalybeate strong enough to taste. The amount of oxygen is greater than the carbonic acid, and to some extent always present, so that the peroxide is found in the water and not the protoxide. As the peroxide is not soluble in water, it forms a milky or turbid fluid which is more or less unpalatable. This turbid state may exist to a very small extent so as merely to take away the brilliancy; even then, however, it is an objection as it affects the appearance and the palate. For this reason pipe-water when apparently very pure will precipitate on standing yellowish flocculent matter. Perhaps it would not be right to say that the water has any taste when in this state, but it is certainly inferior in some respect, less pleasing to the palate. Pipes which are well supplied with oxygen by filling and emptying with water are more apt to oxidize according to experience, and this we might readily expect. This must be known to all who have attended to the state of the water after the pipes had been for some time empty. But the oxidation goes on at all times, as may be seen by putting a little protoxide of iron into the bottom of a glass of water, in a short time it is quite oxidized or

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of a light brown. A piece of iron may also be observed to rust in the same way. It becomes a great nuisance if it comes out of the pipes in great quantities; however, it is probable that no water can be brought through iron pipes without losing some of its purity. The water will wash it away when formed, but if the flow be constant very little will appear at a time; the great safeguard therefore will be found in using a large amount of water.

Hard water seems to be a great preservative of the pipes by incrusting them with lime; it becomes, however, important to know how to preserve them when soft water is used. Whatever is put on iron is after a time removed, no matter how thoroughly the contact be made. It has been proposed to use tinned pipes, made of wrought iron. The covering of tin is in contact with the iron, but even this is not enough, and one is almost inclined to think that the only method of keeping the iron clean is that which engine-men employ—constant rubbing and abundance of oil. It shows us how very insinuating the air is, how it goes into pores of which we could not know the existence, and when it once penetrates under the surface it tunnels onwards in a surprising manner. When iron is covered with tin the two metals unite and form an alloy some depth into the substance of the iron, this alloy gradually decreases in its amount of iron until at the surface there is a covering of pure tin. One would suppose that through this covering no air could possibly go. It does get through, however, not merely from mechanical lesion in the tin, but from the imperfection of the surface and the method of covering. Holes are left excessively minute, but sufficient after a long time to make themselves perceptible by an accumulation of oxide of iron, which they dig out and raise up like mole-hills on the tin plate. The smallest hole will be enough, and it must be a small hole indeed which will not allow the passage of an atom of oxygen. The oxide rises up as it seeks more room than the iron. It is also porous, and becomes in fact an inlet to the metal which is underneath it. As more comes up the hole gets larger, the oxide breaks the tin up in various places, and completely envelopes it in rust. I am not aware that there is any reason to attribute this to galvanic action, which may more properly be supposed to preserve the iron, tin being positive to iron in cold weak sulphuric acid. A similar action goes on even faster with many coverings where there can be no galvanic action. Enamelled surfaces have not, I suppose, been tried for large pipes. I proposed a mode of covering with pitch for the Manchester pipes, which seems to be useful, although there is room enough for invention still. It covers them with a black varnish, which is also a great preservative to the outside of the pipe if the covering is well made. The outside is exposed to drainage, and the pipe is very liable to become entirely wasted away by this action, leaving only its form in the shape of a piece of graphite. It is, in fact, common to find iron exposed to under-drainage, dissolved out in this manner, not breaking off in scales and becoming a mass of rust, but being removed completely, leaving its form only. A piece which Mr. Binney gave me from a colliery near Manchester, consisted of iron 38·8, silica 19·7, carbon 40, and a little oxide of iron. Water-pipes are subject to the same decay when not protected.

20 grains of cast-iron borings were added to 20 ozs. of water, and allowed to stand 24 hours.

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	Oxide of Iron.
1st deep well water, with much carbonic acid .	•15 grains.
Distilled water	•08 „
Water with a little common salt so as to taste	•16 „
Manchester pipe water	•13 „
Water from sewers	•13 „

The water with many salts in it acts most, the purest water least, because there was little carbonic acid or air in the distilled water used here. The oxide was not in solution, and gave little taste to the water. Iron suffers in contact with air, carbonic acid, and soluble salts in water, so that whether it be in contact with water from well-drained land, or badly-drained land, it is still in danger.

The use of lead pipes is common enough; and although the danger from lead has often been pointed out, there is no diminution in the amount used. It is acknowledged that with soft water lead is very dangerous, but I am disposed to think that it is dangerous even with hard, except when a crust forms upon it. When a lead pump is used, no matter how hard the water is, there is still lead to be found in it. In one case I found lead where there were 62 grains of lime salts in a gallon; the family filtered the water, but that did not quite remove it, although it was much improved. This shows the lead to have been in complete solution, although the water was hard. The pump was made of lead, so that there was a constant friction preserving the surface clean and assisting comminution.

In another case where there was a lead pump and well, the water also coming from a badly-drained and putrid underground, the water was acid, and an acid salt of lead was found in the water, strong enough to have a distinct taste of lead, and otherwise nauseous from the other salts, such as nitrates and chlorides. A few bubbles of sulphuretted hydrogen made the whole of a deep brown instantly, and it was lamentable to find that the persons who used it did not suspect any evil from this source.

The use of zinc in lead pipes has been proposed as a remedy, but it is not desirable to drink even zinc. There is a lead pipe made in Manchester covered with tin, a very thin film of it protects it considerably from the action of water acidulated with acetic acid. Probably for water-pipes it may be very useful. It is time that some change should be made in the small water-pipes now made of lead, and that the use of lead pumps and cisterns should be done away with, unless they can be protected.

Dr. ANGUS SMITH on the COATING of WATER-PIPES.

The mode of coating water-pipes, which I proposed for the Manchester water-works, and which they have adopted, was the following;—The pipe is made clean, free from all rust and earth which clings to it on coming from the mould; the cleaning is a very important thing, as the success very much depends upon it. The surface is then oiled with linseed oil, in order to preserve it until it is ready to be dipped.

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When the coating is to be made, the pipe is heated in an oven to about 300° , which should also be measured in such a manner as to prevent soot from coming on it. It is then dipped into a pan of gas pitch, and kept in it for a short time until it shall have taken up the pitch as intimately as is possible. The pitch should not be too hard, so hard as to be brittle, nor should it be too soft, so as to adhere to anything; when it becomes too hard it may be softened by adding more oil.

When the pipe is taken out it is covered over with a fine black varnish, and looks exceedingly well. How long they will last is not easy to say; but if well done they will last longer than any other mode I have seen. I was at one time not inclined to think it of much value, but I saw lately one which had stood out every season, and was still in very good order. I am disposed, therefore, to think that it might be made to endure as long as can reasonably be wished.

The surface of iron is exceedingly difficult to keep clean, and, probably, no plan has ever quite succeeded but that which the engine men employ to keep their machinery bright, that is, abundance of oil and constant scouring. This oxidation shows us how very insinuating the air must be; it goes into pores of which we could not know the existence, and when it once penetrates under the surface it travels onwards in a surprising manner. When iron is covered with tin, the two metals unite and form an alloy some depth into the substance of the iron. This alloy gradually decreases in tin, until at the surface there is a covering of the latter metal alone. One would suppose that no air could go through this covering. It does get through, however, not, I believe, from any mechanical lesion of the surface, but from the imperfection of the mode of tinning. Holes are left excessively minute, but sufficient after a long period to make themselves perceptible by an accumulation of oxide of iron, which they throw out, and raise up like mole-hills on the tin plate. The smallest hole will be enough to begin with, and it must be a small hole indeed which will not allow the passage of an atom of oxygen. The oxide formed rises up, as it seeks more room than the iron. It is also porous, and is then, in fact, an inlet of oxygen to the metal which is beneath it. As more comes out, the hole becomes larger, the oxide rises up and breaks up the tin in various places, completely enveloping it in rust.

Zinc acts to some extent in a similar way; the comparative value of the processes I do not know. There is less necessity, I believe, to bring in the use of galvanism, in order to explain the mode in which iron throws off other coverings. In the case of earthenware glaze it would be difficult to bring it in at all. In any case, however, *oxygen* must be brought in, and the mode of acting with ware will probably be the same as with the tin. In this case, however, we cannot suppose holes in the surface, but rather at the sides or points of junction, where the oxygen may enter; showing the difficulty of making a *complete contact* between the metal and earthenware.

The first part is a copy of what I intended to say on tin, &c., this last part I have written hastily, as I find I am late. I think it is the true explanation; that, namely, which is given to explain the tin will apply to the earthenware. I was not aware, however, that earthenware came off. I have some on a pan which has lasted a long time the joinings are good.

*Professor Way examined.*Professor
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1. You are professor of chemistry, I believe, to the Royal Agricultural Society?—I am.

2. In the course of your investigations, has your attention been directed to the quality of water from different natural sources, and to the effect of soils upon water percolating them?—For many months I have been engaged on a series of experiments, intended to elucidate the action of soils upon the constituents of manure. The results I have obtained, however, equally apply to the composition of natural waters, and I have more lately directed my attention specially to the latter branch of inquiry.

3. What is the nature of the experiments you have made?—My first experiments were made with tubes, of from 12 to 18 inches in length. These tubes having been partially filled with the soil under examination, I poured upon the surface strong solutions of different alkalies, and alkaline and earthy salts. I found that the first portion of the liquid which came through was absolutely deprived of them. Thus, for instance, if a solution of caustic potash, or of ammonia, containing 1 per cent. of either alkali was made to filter through 9 inches of a soil contained in one of the tubes just mentioned, from one to two ounces of liquid passed through quite pure and free from the substances in question.

4. What was the diameter of the tubes you employed?—They were, as I before said, from 12 to 18 inches in length, and from $\frac{3}{4}$ of an inch to $1\frac{1}{2}$ inch in diameter, and would contain, perhaps, when partially filled, from 1500 to 2500 grains of soil. I have since used much larger filtering jars without, of course, any difference in the character of the result.

5. What were the times occupied in percolation?—When a light soil was employed, and the depth of the filtering bed was 9 inches, the liquid would begin to drop through in 8 or 10 minutes; if a stiff clay were the subject of experiment, it would take much longer to filter, perhaps an hour or an hour and a-half. In these cases, the abstraction of the alkaline substances was complete. In order, however, to ascertain whether a sensible time was necessary for the effect, I forced the liquid in one experiment through the soil, by means of a syringe, with precisely similar results, although the soil and the solution were in contact less than a minute.

6. It does not, therefore, require a lengthened time for the exhibition of the power of which we are speaking?—No; such is the conclusion to which my experiments lead me.

7. Your experiments were made, as we understand, with substances *dissolved*, not merely mechanically suspended in water; the action you are describing is, therefore, different from ordinary filtration?—Totally different.

8. If, for instance, you were to filter a solution of caustic potash through pure sand, you would not expect the alkali to be arrested?—Certainly not; sand would merely stop any solid substance suspended in the water, in the same way that the paper filter of the chemist does. Although, even in the case of a sand filter, very minutely divided solid matter would be liable to escape.

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9. Do you consider the effect to be due to surface attraction, or is it a chemical action?—I believe it to be purely a chemical action, and that the different alkalies are absorbed in the relation of their chemical equivalents or combining proportions.

10. You state that ordinary soils possess this power, whilst pure sand does not; to what ingredient of soils do you attribute it?—I have good reason to believe that the action is due to the clay contained in most soils. I have already stated that sand does not possess the power, whereas a clay, with which I have made many experiments, exhibits the property in a high degree.

11. What kind of clay was that?—The specimen particularly alluded to was a white clay, of the “plastic clay” formation used for pottery. I selected this for my experiments, because it contained no perceptible quantity of organic matters, and well represented the class of pure natural clays.

12. With what other descriptions of soils have your experiments been made?—With three or four loams of different qualities and agricultural value; one of these being the thin soil on the chalk hills of Dorsetshire (Mr. Huxtable’s farm), another from Mr. Pusey’s estate in Berkshire; also with one or two *agricultural* clays, contradistinguished from the pottery clay before mentioned.

13. In all these cases have the experiments been made with soil free from vegetation?—Yes; there was of course *vegetable matter* in many of them, but no living vegetation.

14. In point of fact, you believe that the effect observed is due to the mineral matter of the soil, and not to plants of any description growing in it, or to vegetable matter in any form?—Most decidedly; that such is the case, is put beyond a doubt by the experiments I have made with potters’ clay dug from a depth of 20 feet, and containing no appreciable quantity of vegetable matter.

15. You mentioned that the alkalies and alkaline salts were arrested by filtration through soils; will you state to what salts you have extended your observation?—I have found that the alkalies potash, soda, and ammonia in their caustic state, or in the state of carbonates, are absorbed by soils; in the case of all other salts of these alkalies, such as their sulphates, muriates, or nitrates, the *base only* is arrested, the acid of the salt passing through in combination with lime derived from the soil. Thus, if a solution of sulphate of ammonia is made to filter through a soil which itself yields no soluble salt of lime to water, the ammonia is left in the soil, whilst abundance of sulphate of lime is found in the filtered liquid. The presence of lime in a soil enables it not only to arrest the alkaline carbonates, but the alkaline base of all such other combinations.

16. That is to say, if a solution of any of the ordinary salts of potash, soda, or ammonia is filtered through a soil, the filtered liquid no longer contains such salt, but has taken up in its place a corresponding salt of lime?—Precisely so. If I filter muriate of soda (common salt) through a soil, and analyze the resulting solution, I shall find in it exactly as much muriatic acid (chlorine) as in the original solution; and in the place of soda, I shall obtain a corresponding quantity of lime; in other words, for muriate of soda I obtain an equivalent quantity of muriate of lime.

17. What would be the effect of passing this filtered solution through a second bed of the same soil? would the muriate of lime be removed by such a process?—Certainly not; the soil has no further power. Indeed, in any filtration of a limited quantity of liquid through a bed of soil of considerable thickness, this double filtration does in reality occur. The change takes place in the first instance in the upper portions of the soil, and the altered liquid has subsequently to pass through a stratum of fresh soil, and yet we find that the *very first portions that pass through*, contain a salt of lime corresponding to the alkaline salt that has been used in the experiment. This is the practical result, and it is easy to see that it should be so. The arresting power of the soil is for the *alkaline base*, not for the whole salt; but it is out of the question that such an action should take place, unless there were something present to combine with and saturate the *acid* of the compound. Lime performs this office for the salts of all the other alkalies and alkaline earths; but its own salts must be an exception to the general rule.

18. Then you are quite unable, by filtration through a soil, to remove from water any of the salts of lime it may contain?—Not exactly so. I before stated, that, besides the caustic or free alkalies, the soil had the power of removing from solution the carbonates of these bases, and that without introducing into the liquid any corresponding salt of lime. In the same way lime, when dissolved in water, as it exists in *lime-water*, which is a solution of caustic or free lime, is entirely separated by filtration through a soil. Carbonate of lime also, when dissolved in water by means of carbonic acid, is entirely removed by passing the water through an ordinary soil or through a pure clay.

19. Then, if I understand you aright, in operating upon a solution of lime, part of which is in the state of carbonate, and part in the state of sulphate and muriate, you can, by filtration, entirely remove the carbonate of lime; but your filter bed will not arrest any portion of the other salts I have named?—Just so. I may further observe, that all the ordinary salts of lime being soluble, are washed from the soil by the water of rain passing through it, which would not be the case, were they compounds, which the soil possessed the power of combining with and arresting.

20. Have you made any experiments to ascertain the extent of this power of soils, and can you state to what amount the abstraction of salts by such filtrations would occur?—I have made a great number of accurate experiments on this point with different soils, and with solutions of salts of ammonia, potash, soda, lime, and magnesia, &c., of various strengths. The method of filtration was not in all these cases adopted, although convenient; it is, indeed, unnecessary to the success of the process; for the power of soils to unite with the alkaline bases is so marked, that you have only to stir up with the solution a quantity of the soil, allowing it afterwards to subside, and the clear liquid will be found either entirely free from the alkali employed, or sensibly diminished in strength. I find that an ordinary loam will absorb about $\frac{3}{10}$ ths per cent. of its weight of ammonia, and about one per cent. of potash, and so on for the other compounds of which we have been speaking. This quantity appears small, but it is in reality enormous, when the weight of a given area of soil is considered. Thus, for instance, the soil of an

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acre of land one inch deep will weigh about 100 tons, or 10 inches in depth 1,000 tons. This quantity of soil would therefore arrest, and combine with three tons of ammonia, or 10 tons of potash. To furnish three tons of ammonia, 15 tons of sulphate of ammonia, or nearly 20 tons of Peruvian guano must be employed; so that I am justified in saying that this property of soils is, practically, enormous.

21. To what extent does the separation of carbonate of lime by filtration go?—Under the most favourable circumstances, that is to say, by stirring up the materials, so that every portion of them should come in contact, I find that 100 parts of a soil will absorb about $1\frac{1}{2}$ parts of carbonate of lime; or, comparing this with the previous illustration, you will perceive that an acre of soil 10 inches in depth would arrest 15 tons of carbonate of lime. And we may form a further idea of this power in altering the chemical composition of water, by calculating the effect which the filtration through a soil would have upon Thames water. Supposing this water to contain 14 grains of carbonate of lime in the gallon, it would be found, from the above data, that an acre of soil 10 inches deep would remove the carbonate of lime of about 17,000,000 gallons; or, if the water have to pass through five feet of soil before reaching the drains, 100,000,000 gallons would be purified by the filtration.

22. Your results appear to have a close and practical bearing upon many of the operations of agriculture. But, confining our attention now to the composition of water, will you state what general conclusions as to the quality of water from different natural sources you would be inclined to draw from a knowledge of this property of soils?—Bearing in mind that I attribute the power in question to clay, I should expect that rain-water, falling on a sand, would wash out from it any soluble salts it happened to contain, until, in the lapse of years or ages, nothing soluble remained to be washed out. Falling on a loam or open friable soil, containing a certain portion of clay, it would wash out from it only the soluble salts of lime, such as the muriate and sulphate, if these happened to exist in it. Supposing this soil to be in cultivation, I conceive that none of the salts of the manure would be washed out by rain, except, as I before stated, the soluble salts of lime; but the proportion of such salts washed out by rain would exceed that supplied in the manure, inasmuch as the salts of the other alkalies would be transformed into salts of lime, and be equally liable to be carried away by drainage water. The more perfect the drainage, the more regularly would the water percolate the soil, and every portion becoming active, the more certainly would the valuable salts of manure be arrested to the fertilization of the soil and the purification of the water. Lastly, rain-water passing through a stiff clay soil, providing that it had been well drained, and time had been allowed for the drainage to take effect, would, I conceive, be still less likely to bring away with it any other salts than those of lime before mentioned. If such a clay happened to be free from gypsum, the most common soluble salt of lime, the drainage water would be contaminated only with those compounds of lime derived directly or indirectly from manure, and it would be easy to demonstrate, that the quantity of such salts would, in reference to the rain-fall, be very inconsiderable.

23. Then in good cultivation you include good drainage?—Certainly;

efficient drainage of soils, not by surface-drains, but by drains at a proper depth, amongst other advantages, seems to offer the additional one of distributing the manuring substances artificially applied, or derived from the atmosphere by rain, through every part of the soil; by this equable distribution of the salts of manure, a perfect immunity from loss is secured.

24. Have you analyzed any drainage-waters?—As yet, I have not completed any analyses of drainage water of a sufficiently pertinent character to be described here. I have, however, arranged with Mr. Parkes the plan of an extensive inquiry into the actual quality of the water of drainage from different descriptions of soils.

25. Without asking you the particular composition of the waters of land drainage, could you state any facts relative to the general characters of such waters?—I am not personally possessed of sufficient information to give an opinion on this subject; but I have been told by Mr. Parkes, to whose experience on such questions I should attach great weight, that the water of deep drainage, especially on clays, was found to be beautifully clear and sparkling, and in many cases of a softness closely approaching to rain water. This statement has been confirmed by all those experienced in drainage of whom I have made the inquiry. One gentleman living in Essex (Mr. Majendie) has told me that having drained some time since some clay lands on his estate, a number of cottagers living near the outfall asked his permission to use the drainage-water for domestic purposes in preference to their usual supplies.

26. You have described the circumstances which would influence the water of drainage; would the same observations apply to land-springs and shallow wells generally?—Yes, the composition of such water would probably be regulated by the character of the superficial strata in the immediate neighbourhood.

27. You are no doubt aware that the water of the artesian wells in the chalk contains a considerable quantity of alkaline salts. How do you account for this circumstance?—The water derived from any stratum will always take the character of that stratum provided there is anything in it that water is capable of dissolving out. In both the upper and lower chalk, many specimens of which have been analyzed in my laboratory, potash and soda have been found in very considerable quantity. These I believe exist partly in the form of silicates, and partly, perhaps, in the form of a double carbonate of lime and potash, or soda, which is of very slight solubility. It is easy to see how water containing an excess of carbonic acid, as the water of the chalk does, would gradually liberate and dissolve out the alkalies from it.

28. Supposing you were to apply the results of your experience to the practice of collecting and storing water, and supposing it were desired to obtain water which had fallen on the surface in the greatest purity, would your experience enable you to express a confident presumption in favour of filtration by percolation through the soil as a means of obtaining pure water rather than collecting it off the surface?—Certainly. My experiments would lead me to believe that water which had percolated the surface-soil to any depth, from 2 to 6 or 8 feet, would, as a general rule, be purer than water either flowing over the surface or taken from greater depths. I have found that different soils possess the power of removing salts from water to a different extent. Water

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which has passed through surface-soil is deprived of its salts to a greater extent than water passing through a soil which has never been cultivated; and there are some kinds of soil (those least fitted for cultivation) which would give up to water any salts they might contain rather than serve to purify it. It is for this reason that I believe that water percolating cultivated soils would, on the whole, be freer from salts than that collected on the surface or taken from great depths.

29. Would not water, after having passed through one description of soil and lost its salts be likely to obtain more mineral matter in percolating other varieties of soil?—Yes; I have before observed that water will possess the character of the rock through which it last flows and from which it issues, unless in the case of sandstone districts, which probably neither give to or take anything from water. I think, however, that from what we now know of the action of clay upon water, we may safely conclude that many other strata of the earth besides the deposits of clay will possess the power of greatly modifying the character of any particular water.

30. Does your experience enable you to prefer any kind of earth, looking to the agricultural objects, namely, the retention of a certain quantity of the salts required, and to the sanitary object of having the water free from such salts as would be injurious or useless? Can you, in fact, point to any one description of soil that, for domestic purposes, would form a better filter than others, supposing the filtration to be by shallow drains near the surface?—I attribute the property in question solely to the clay; and I believe that the circumstance of surface-soils (such as those mentioned before as containing only 30 or 40 per cent. of clay) possessing this power in greater intensity—weight for weight—than pure natural clay, is due to the production of a greater amount of the active substance in those clays which, by cultivation, are exposed to atmospheric and other agencies; but there is plainly a distinction to be drawn between the circumstances most favourable for the mere *collection* of water comparatively pure, like rain-water, and those which would conduce to the purification of a water impregnated with salts, such as the water of all rivers.

31. For the collection of the rain-fall of a given district, what soil would you prefer?—I should say decidedly a sand. Rain-water, when collected at a distance from towns, is fit for every purpose, and contains, I imagine, little which in a sanitary or domestic point of view it would be important to separate. All that is required from the collecting surface in this case is, that it shall perform its office without imparting to the water anything to render it impure. Sands which have been washed by rain for ages are most likely to fulfil this condition, and would possess the further advantage of allowing the ready escape and collection of the water.

32. Have you analyzed the specimens of water given to you by Mr. Paine, of Farnham?—I have examined them to a certain extent.

33. Will you state the result of that examination?—The specimen which I operated upon was obtained by Mr. Paine and myself from the commons near Farnham, being collected from a small well near its source through which the water flows in its way to the town. I found it bright and sparkling, and quite different to what we are in the habit of recognizing in rain-water, which is usually collected in a manner very

unfavourable to its qualities for domestic or other purposes. The total quantity of salts of any kind in a gallon of this water proved to be 1·5 grains, which so far as I am aware is as small a proportion as is found in any considerable body of natural water from any source. The proportion of lime I found to be ·168 grains in a gallon, which is equivalent to exactly $\frac{3}{10}$ ths of a grain of carbonate of lime in the gallon, or $\frac{3}{10}$ ths of a degree of hardness of Dr. Clark's test.

34. Was the whole of this lime in the state of carbonate?—I am inclined to think not, since a considerable quantity of chlorine was found in the water, most probably existing as muriate of lime. My analysis of the water has not, however, been complete, for one reason amongst others, which a chemist would readily understand, that is to say, that the water contains so little salt of any kind that it is difficult to evaporate enough of it for analysis without running the risk of introducing as much impurity from the vessels, &c., used in the process as the water itself contains.

35. How would you account for the presence of muriate of lime, or in fact of any salt at all in the water, seeing that it falls on a sand through which millions of gallons of rain-water must have passed in the same way?—It is difficult to answer that inquiry. The sand in question is not a chemically pure sand; but besides the vegetable mould at its surface bearing ferns and heath, veins of clay, intermixed with sand, run through it. It seems to me that the muriate of lime is derived from common salt, brought down by rain and changed by its passage through the little clay in the soil into a corresponding salt of lime. Sea breezes are known to carry common salt many miles into the interior of the country, and the Farnham commons would readily be reached in this way from the south and south-west.

36. Would the muriate of lime be objectionable as an ingredient of water to be employed for drinking and general domestic purposes?—We know little or nothing of the effects upon health of infinitesimal doses of different salts when taken constantly in water; but assuredly if so small a quantity of a salt of lime be objectionable, no natural water on the face of the earth is fit for drinking. As for the hardness of the Farnham water, I have already stated that it only reaches $\frac{3}{10}$ ths of a degree of hardness, that is to say, $\frac{1}{5}$ th of the average hardness of the Thames at Hammersmith.

37. In both a sanitary and an economical point of view you would, then, consider such water of proper quality for the supply of the metropolis or of any large town?—Undeniably; I have before stated my belief that rain-water collected in a pure atmosphere, and on surfaces uncontaminated with decaying animal or vegetable matter, or with soot, &c., is the most perfect form of water. It is, in fact, the nearest approach to *distilled* water; but having the advantage over artificially distilled water of being well aerated, and therefore agreeable to drink. I consider the water of Farnham, of which we are speaking, to be *rain-water*, collected in the most unexceptionable manner that is practicable on the large scale.

38. What would you recommend as to the treatment of such collecting surfaces for improving or preserving the quality of water so derived? what sort of vegetation would you encourage? or would you take measures to destroy, as far as possible, all kinds of vegetation?—I would

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certainly encourage some sort of vegetation, in order that the ammonia and other matters, mineral and organic, brought down from the atmosphere might be used up, and prevented from contaminating the water. I do not feel competent to give an opinion as to the kind of plants which it would be best to have on these collecting grounds, but they should be such as would not need the application of manure of any kind ; an application which, on such a soil, would directly or indirectly be productive of injury to the quality of the water. It would of course be desirable that if any kind of produce could be made to grow on such soils without manure, it should be such as to repay the cost of collection ; and for the same reason that I should object to direct manuring, I should object also to the extensive feeding of cattle, or stock of any kind on that produce as it grows.

39. You mean that the produce, if any, should be carted off the land?—Decidedly ; and I mean, further, that in order to keep up the balance in the composition of the soil, and to prevent the accumulation of matters derived remotely from the atmosphere, a certain quantity of produce should, in a given time, always be removed.

40. Has no kind of plants occurred to you as likely to meet these requirements?—Perhaps *gorse*, if it could be made to grow in such soils would be the very best produce to encourage ; a canal or canals running into the Thames pass through the very centre of the district. Gorse, when properly prepared, has been found an excellent food for stock ; and I have heard that its good effect upon horses, racing and pleasure-horses especially, is remarkable. It has been used, I believe, in the stables at Ascot, and gives a singularly smooth coat and other healthy character to horses fed upon it. I can conceive that being properly packed, it would economically be brought by barges to London for the use of stable and cow-keepers, and afford a profit upon its cultivation.

41. Does your observation enable you to say whether gorse or furze would grow on such commons?—I cannot say. I have seen it on the same kind of soil in many parts of Surrey and in parts of Kent, as at Tunbridge Wells (where the soil is a gravelly sand), on what is called by geologists the “Hastings sands,” gorse flourishes in great luxuriance. It is said, however, to delight in a heavy clay subsoil ; and it may be doubted whether the sandy commons would be suitable to it, except where the clay below comes tolerably near to the surface.

42. You are then clearly of opinion that, for the preservation of the water in its integrity, the collecting grounds should not even, if otherwise practicable, be brought into general cultivation?—Yes, unless by the admixture of clay the manure-retaining properties of the soil could be increased.

43. We have hitherto spoken of the circumstances affecting the quality of water as regards salts and other mineral impregnations. Do you possess any information bearing upon the vegetable or animal substances occurring in water, and the possibility of purifying water so contaminated?—My experiments on soils have been extended with considerable success to this branch of the question. I have passed various animal and vegetable solutions, such as stinking cow’s urine, sewer-water, putrid human urine, the water produced by the steeping of flax, &c., through filter-beds of soil ; and when passed through they have

been entirely deprived of smell and taste, except an earthy smell derived from the soil.

44. Were these solutions offensive to the smell?—Yes; they were highly offensive and coloured; and the liquid dropped from the filtering-soil so colourless and inoffensive, that it might be even tasted without disgust. It was, in fact, a mere solution of various salts of lime.

45. You think that mechanical separation of suspended animal and vegetable matter would not have produced the same result?—Certainly not. I have over and over again filtered these same liquids through beds of fine sand, without in any degree removing these offensive properties. And as in the case of the absorption of potash, ammonia, &c., by soils, this deodorizing process can be effected without filtration by simply stirring up the liquid and the soil together; when this latter subsides, the solution will be found colourless and devoid of smell and taste.

46. Are you aware that it has been stated that in the surface distribution of sewer-water by jet or hose, all trace of smell disappears in half an hour after the manure has been applied to pasture-land?—Yes; and although no doubt plants begin the absorption of manure in solution immediately it is presented to them, there is no doubt that the observed effect is due to the soil and not to the plant, and that the result would be the same if the sewer-water were applied to arable land not at the time bearing a crop.

47. Do you attribute the effect of soils upon organic matters also to the clay contained in the soils?—Yes.

48. By filtration of the water of rivers containing salts, giving hardness and different animal and vegetable matters in solution through a bed of soil, you can remove all these and produce comparatively pure water?—I can, with the exception of those salts of lime before enumerated, and such other salts of lime as will be formed from alkaline sulphates, muriates, and nitrates. I have in this way reduced Thames water of 15 degrees of hardness (15 grains of carbonate of lime in the gallon) to less than 2 degrees of hardness, and rendered it soft and pure.

49. Do you imagine that any such filtering process is applicable to the preparation of water for towns like London?—It would require great and careful consideration to give a satisfactory answer to that question, the quantity of water required for London being so enormous; but I should by no means despair of its applicability to other towns where the necessary supply is more limited.

Second Examination.

1. What do you conceive will be the effect of soft as compared with the common hard water for the reception and removal of human fæces and urine, and its application as manure?—I am not aware that in this point of view soft water would possess any notable advantage over ordinary hard water.

2. What will be the effect of the immediate reception of such matter

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in cold water, and its immediate removal in cold water, as compared with the effect of its removal after exposure to the atmosphere during one or several days, the effect upon the productive value and quality of the matter as manure?—As a question of the agricultural application of sewage manure, there is an easy answer to this on general principles. The offensive smells and noxious gases that are given off in defective sewerage are for the most part caused by those substances which are the most valuable ingredients of manure, that is to say, by the compounds of nitrogen, sulphur, and perhaps of phosphorus; just in proportion, then, as our noses are offended and our health undermined by these exhalations will be the loss suffered in the manuring power of the matter which gives rise to them.

3. What do you expect will be the nature of the emanations from fæces immediately received and removed in the proportion of half-a-gallon to one gallon of cold water each time of discharge?—The fæces and urine when first voided have but little smell, and that little in the case of the former is, I imagine, due to the biliary and other secretions, and in no way connected with the escape of any notable quantity of gaseous matter. It is not until after these have been exposed for some time to the combined action of air and water that decomposition can commence, and noxious gases be given off. If, therefore, the fæces and urine could be received in the quantity of water you mention, and at once removed by it, the cause of offence to the senses and the health would, it should appear, be reduced to a minimum.

4. Since your last examination you have, I believe, received another quantity of water from Farnham?—I have.

5. Have you made any analysis of it, and if so, describe the results you have obtained?—I have made a tolerably complete analysis of this second specimen, and find it to differ considerably from the one before sent to me. It is right that I should mention that, in forwarding the jars of water at my request at the early part of last month, Mr. Paine informed me that, owing to the unusually heavy rains, and to the very recent cleaning out of the wells through which it has to pass in its progress to the town, the water was by no means in its ordinary condition; circumstances, however, would not allow of my delaying the analysis till another sample could be procured. I found this water to contain 5·191 grains of solid matter in the gallon, or more than three times as much as the previous specimen. The following analysis exhibits the composition of this solid residue:—

	Grains.
Organic matter and combined water .	1·245
Silica	·550
Lime (as silicate?)	·375
Sulphate of lime	·280
Sulphate of magnesia	·557
Chloride of magnesium	·522
Chloride of sodium	1·440
Chloride of potassium	·354
	5·323

This water is very peculiar in one respect; it contains, so far as I

have been able to observe, no trace of carbonate of lime, or of any other earthy or alkaline carbonate. The product of the evaporation of upwards of two gallons of the water (the final evaporation being effected by a heat short of 300° Fahrenheit) did not give a perceptible effervescence with hydrochloric acid. The presence of organic matter which, in the former instance, was barely recognizable, together with the comparatively large proportion of common salt, and of other chlorides, sufficiently convinces me that the water had been affected by disturbing causes of an unusual character.

6. You think, then, that the sample of which you have given the analysis would exhibit, in all probability, the latitude of impurity to which the water of the Farnham commons is liable?—Taking all the circumstances into consideration, and comparing the results with the partial examination which I made of the former specimen, I should say—yes.

7. In this its worst condition, would the water, in relation to its application to domestic and other purposes, be preferable to that now generally supplied to the metropolis?—I have no doubt that it would; the degree of hardness was, 2° and although less bright than at other times, it was still wholesome and agreeable to drink.

8. Does it occur to you that, in addition to the general causes of disturbance to which you have alluded, any other local cause may have contributed to render this particular specimen of water less pure than usual?—I have not made inquiries upon this point, but I can quite conceive that if the soil of the garden or gardens beneath which the pipes are carried, and in which there is access to it by small bricked wells as I before described, had been lately manured, some portion of the manure might have found its way into these wells, and thus contaminated the water. The soil of the gardens must in most respects closely resemble that of the commons, which is, by its sandy nature, and the comparative absence of clay, very little adapted to retain manure; and although I am not prepared to say that such has been the case, it is not impossible. The water was examined for nitric acid, which (from Dr. Smith's experiments) should be one of the products under such circumstances, but it could not be detected. I may be allowed to remark, in this place, that the bare possibility of such a contamination having taken place shows the necessity for the precautions (with regard to manure, &c.) which I have before urged, in case these sandy commons should be used as gathering grounds for the supply of the metropolis with water.

9. Have you in the course of your agricultural inquiries turned your attention to the employment of sewage as manure, and to the mode by which it might be made most generally available?—This subject has, as might be expected, appeared to me, as to most persons engaged in the same pursuits, of the very last interest and importance, and especially in relation to the experiments on the absorptive powers of soils I have before described.

10. Have you analysed the contents of any London sewer?—I have.

11. Would you describe to the Board the nature of your examination of sewer water?—Two specimens of sewer water were sent to me by direction of the Board from the office of the Commission of Sewers.

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The one of these was taken from a sewer in Dorset-square, the other from a place called Barratt's-court. The analyses were made for me by Mr. Ogston. In analyzing them measures were taken to separate the solid suspended matter from that actually in solution, so that the manuring nature of each might be clearly ascertained. The solutions were strained through a fine cloth; the solid substances were dried, and the quantity of salts in solution ascertained by evaporating the liquid with proper precautions to avoid loss of ammoniacal salts. The following table shows the relation between the soluble and suspended matter:—

No. 1, from Barrett's-court.

The imperial gallon contained—

Of substances in solution . . . 243·30 grains.
Of insoluble substances . . . 248·96 „

No. 2, from Dorset-square.

In the imperial gallon—

Of substances in solution . . . 109·00 grains.
Of moveable substances . . . 100·70 „

The quantity of substances at any time present in a given quantity of sewer water will be dependant on many circumstances, particularly on the time of collection and the nature of the water supply. This circumstance accounts for the first specimen containing twice as much matter dissolved in the solid state as No. 2. The relation between these is, however, of equal importance, as their total quantity in reference to the water and in the two cases a certain proportion between soluble and insoluble is retained. But I am not prepared to say that such an uniformity would be found to obtain in other specimens. The following tables exhibit the composition of the soluble and insoluble substances in these specimens of sewer water.

ANALYSIS OF SEWER WATER.—No. 1. From Barrett's Court.

	An Imperial Gallon contains (in grains and tenths).—		
	Soluble.	Insoluble.	Both.
Organic Matter and Salts of Ammonia . . .	121·50	180·32	301·82
Sand and detritus of the Granite from the Streets	*1·39	19·30	20·69
Soluble Silica	1·57	10·94	12·51
Phosphoric Acid	7·71	2·73	10·44
Sulphuric Acid	10·71	4·02	14·73
Carbonic Acid	11·62	3·97	15·59
Lime	7·50	17·03	24·53
Magnesia	2·87	Traces.	2·87
Peroxide of Iron and Alumina	Traces.	6·20	6·20
Potash	46·91	1·22	48·13
Soda	None.	1·51	1·51
Chloride of Potassium	None.	None.	None.
Chloride of Sodium	31·52	1·72	33·24
	243·30	248·96	492·26

* This is some small proportion of insoluble matter escaping the linen filter, and properly belonging to the other column.

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The insoluble and soluble matters are both capable of supplying nitrogen or ammonia to vegetation. The solution contains the nitrogen in the form of ammoniacal salts, and it is a circumstance of great interest and practical importance that *all the nitrogen* in the liquid state seems to be in the form of ammoniacal salts—the urea and other animal products having rapidly passed into this condition. The insoluble matter contains, of course, no ammoniacal salts, its nitrogen being referable to unchanged animal matters. The quantity of ammonia in the soluble and insoluble state in a gallon of sewer water, calculating the nitrogen of the solid matter as if it had passed into ammonia, is as follows:—

Ammonia in a gallon—
In the soluble state . . . 36·72 grains.
In the insoluble state . . . 4·56 „

ANALYSIS OF SEWER WATER. No. 2.—From Dorset Square.

	An Imperial Gallon contains (in grains and tenths.)—		
	Soluble.	Insoluble.	Both.
Organic Matter and Salts of Ammonia . .	57·32	23·00	80·32
Sand and detritus of the Granite from the Streets	0·78	44·50	45·28
Soluble Silica	1·16	12·09	13·25
Phosphoric Acid	2·53	1·64	4·17
Sulphuric Acid	0·28	3·63	3·91
Carbonic Acid	10·58	1·99	12·57
Lime	7·40	8·37	15·77
Magnesia	·07	Trace.	·07
Peroxide of Iron and Alumina	Trace.	2·66	2·66
Potash	2·60	0·72	3·32
Soda	None.	None.	None.
Chloride of Potassium	None.	None.	None.
Chloride of Sodium	27·27	2·10	9·37
	109·00	100·70	209·70

Ammonia :—
In the soluble state 15·16
To be formed from the soluble matter . 2·80

It will be observed that the most valuable elements of the nutrition of vegetables reside chiefly in the soluble portion of the sewage water. The greater part of the nitrogen (ammonia) of phosphoric acid, sulphuric acid, and potash, being found in solution. Any process, therefore, of ordinary filtration or deposition, by which the solid portion only could be rescued, would be very imperfect.

Supposing the sewer water you have analyzed to be thrown upon a soil, would these valuable matters you have mentioned be arrested by the manure-retaining properties of the soil, or would they in any degree be lost?—I have made an experiment upon this point, and with the permission of the Board I will describe it. A quantity of a loamy soil was placed in a glass cylinder to the depth of 6 inches, upon this a quantity of the sewer water, No. 1, was thrown; it began to pass through in about 10 minutes, and in two hours afterwards a quantity

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rather more than equal in weight to the quantity of soil employed has passed through. The solid matter of the sewer water was, of course, arrested mechanically. The clear liquid being analyzed furnished the following results:—

The quantity of solid matter in a gallon being 248·50 grains.

Organic matter <i>containing no nitrogen</i>	60·58
Chloride of sodium	52·73
Chloride of magnesium	·67
Chloride of calcium	8·89
Carbonate of lime	104·98
Sulphate of lime	17·49
Loss on the analysis	3·16
	248·50

The liquid contained no potash, no ammonia or nitrogen in any form, and no phosphoric acid. The soil had, therefore, deprived it of its most valuable ingredients.

Then in the application of sewer water to a good well-drained permeable soil you would not fear loss of the manuring substances by the escape of the water in the drains?—Certainly not. The experiment I have just mentioned would be an absurdly exaggerated manuring by sewer water. In filtering its own weight of water through the soil I am employing a dose of manure that would never be given in practice. Thus supposing the active surface to be 10 inches deep, it would, as before stated, be 1,000 tons in weight on an acre. Now 1,000 tons of sewer water would be 224,000 gallons, which, according to the analysis, would furnish about half a ton of real ammonia, and other things in proportion. In other words, to put on a quantity of sewage of this strength, equal to the weight of the soil to 10 inches deep, would be to manure an acre of land with three tons of Peruvian guano, which is fully 20 times the quantity that would actually be used. Therefore, I say that in practice this power of the soil would, doubtless, give much more favourable results than were obtained in my small experiments.

Have you formed any calculation of the money value, in an agricultural sense, of the water of sewage, supposing means existed for its ready distribution?—It would not be difficult to obtain an approximation to this result if our calculations were based upon the composition of any particular specimen. Thus the Barratt's-court sewer gave about 37 grains of ammonia in a gallon in the liquid state, and about $4\frac{1}{2}$ grains more that would be formed from the animal matter not dissolved. Calling this 40 grains altogether, we should have in 100,000 gallons about 570 lbs. of real ammonia. The recognised value of ammonia, as shown by the price given for Peruvian guano, is about 6*d.* a pound, so that the ammonia alone of this 100,000 gallons of sewer water is worth more than 14*l.*

And the potash, phosphoric acid, and other substances, would make a material addition to this value?—Yes.

Third Examination.

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1. At the request of the Board, you lately visited, in company with Dr. Smith, a portion of the Surrey commons, with the view of examining the water on the spot: be good enough to describe the result of your examination?—I have twice within the last fortnight accompanied Dr. Smith into Surrey. On the first occasion (the 11th of May) we visited the Bagshot district; examining all the streams and collections of water near Farnborough, Bagshot, Chobham, Pirbright, &c., including an area of perhaps more than 50 square miles. On the second occasion our attention was directed to a district to the south of the above, comprising the country between Guildford, Dorking, and Godalming, and their respective neighbourhoods.

2. What was the general character of the water of the Bagshot district?—The water running from the sandy commons was in general very soft; it was, however, in many cases impregnated with peaty matter, which gave it a brown colour, and in some instances it had a perceptible taste of iron; both of which circumstances are of course objectionable.

3. Did you consider that the peaty and irony taste were a *necessary* condition of that water; or would it, do you think, be possible to avoid these characters, so that the water of the districts of which we are speaking might be safely used with that of the other districts where these objectionable characters do not obtain?—From all that I saw, I was led to the conviction that the water, if properly collected, would be free from these impurities; or that, supposing it impossible to *prevent* the contamination, it would be easily and economically removed.

4. Can you state any circumstances seeming to justify this conclusion? first in regard to the water obtaining the peaty matter and iron; where do you think it obtains these?—A large part of this district is covered to a variable, but, I believe, small depth with peat mixed with iron sand, which may be supposed to yield both these substances to water. It does not appear to me, however, that the rain-water in falling and sinking *through* the surface dissolves them, or, if it does, I think that they are removed in the passage of the water through the sand at a greater depth. My reason for thinking as I do is, that small wells to the depth of perhaps two or three feet on these commons furnish water of good quality and quite free from peaty or irony matter; and again the Farnham water which I have before described, and which is obtained from land of a similar quality in most respects, is quite free from such matters; no doubt, because it is obtained *from beneath* the surface. The water appears to dissolve the peat in passing through the natural conduits or small streams on the surface, where it attacks the vegetable matters on the banks assisted by the full action of the air.

5. Drainage by pipes at a short distance from the surface would then seem the remedy for this state of things?—It would appear so, and it is in accordance with the successful experiment in collecting such water at Farnham.

6. You stated that if the water so collected should prove to be peaty, or impregnated with iron, it might readily be purified; how do you imagine this would be done?—Dr. Smith and I observed that the water, in flowing in the shallow streams, deposited large quantities of ochreous matter on the pebbles at the bottom, and just in proportion as this occurred, so the water seemed to get purer. The streams were

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better as they reached the outskirts of the district than they were near the peaty centre, and altogether the water seemed to purify itself in running. One instance of this view, which might indeed in some degree be referred to the purifying power of clay, may be worth mention. A stream at a certain point north of Woking Common was found to be unexceptionable in colour, taste, and softness. Two miles further up, towards its source, it was peaty and bad tasted. The country between these points was of very different character to the general district, being a tolerable soil, and in cultivation. It is possible, therefore, that the effect might in part be due to the action of the clay banks, upon the water running between them. But, whatever the cause, it would appear easy to imitate it, when it is fully understood.

7. You think, then, that the water of the Bagshot district will be eventually obtained in a condition of satisfactory purity?—I believe that, if it should be found impracticable by under-draining, or attention to the natural surface-conduits, to obtain it free from peat and iron, these substances will be readily removed by simple processes in imitation of those which are found naturally to purify it.

8. What opinion did you form of the water in the neighbourhood of Guildford, Dorking, and Godalming?—The stream and pieces of water were for the most part soft, and otherwise good water; in some cases, indeed, remarkably soft. The quantity of water did not, however, appear to be great; but of this I can form no proper opinion. The district is for the most part rich, and consequently cultivated; it would therefore, I presume, not admit of the same means for collection of water as the sandy wastes in other parts of the county.

Examination of Samples of Water from Street Drainage, taken from the Gullies in the Sewers during the rain of 6th May, 1850.

The waters were all more or less turbid, and some of them gave off very noxious odours, due principally to the escape of sulphuretted hydrogen gas.

Some of them were alkaline to test-paper, but the majority were neutral.

The following table exhibits the quantity of matter (both in solution and in the solid state) contained in an imperial gallon of each specimen.

STREET WATERS.

Number of Bottle.	NAME OF STREET.	Quality of Paving.	Quality of Traffic.	Residue in an Imperial Gallon.		
				Soluble.	Insoluble.	Both.
1	{ Duke-street, Manchester-square }	Macadam	Middling	Grains. 92·80	Grains. 105·95	Grains. 198·75
7	Foley-street (upper part) .	„	Little	95·13	116·30	211·43
5	Gower-street	Granite	Middling	126·0	168·30	294·30
12	Norton-street	„	Little	123·87	3·00	126·87
3	{ Hampstead-road (above the canal) }	Ballasted	Great	96·00	84·00	180·00
4	Ferdinand-street	„	Middling	44·00	48·30	92·30
2	Ferdinand-place	„	Little	50·80	34·30	85·10
10	Oxford-street	Granite	[[Great	276·23	537·10	813·33
6	„	Macadam	„	194·62	390·30	584·92
11	„	Wood	„	34·00	5·00	39·00

The influence of the quality of the paving on the composition of the drainage water is well seen in the specimens Nos. 10, 6, and 11, all of them from Oxford-street, the traffic being described as "Great."

The quantity of soluble salts is here found to be greatest from the granite matter from the macadamized road, and very inconsiderable from the wood pavement.

The same relation between the granite and macadam pavement, seems to hold good in the other instances; the granite for any quality of traffic affording more soluble salts to the water than the macadam.

The ballasted pavement holds a position intermediate between the macadam and the wood, giving more soluble salts than the wood, but less than the macadam.

The quantity of solid (insoluble) matter in the different samples of water, which is a measure of the mechanical waste of the different kinds of pavement, appears also to follow the same relation as that of the soluble salts; that is to say, granite greatest, next macadam, then ballasted, and lastly wood pavement, which affords a quantity of solid deposit almost too small to deserve notice.

The influence of the quality of traffic on the composition of the different specimens of drainage is well-marked in nearly all cases; the greatest amount of matter both insoluble and soluble being found in the water obtained from the streets of great traffic.

It is worthy of notice, however, that the composition of the water is very much the same for similar qualities of pavement in those streets where the traffic is described as "Middling, or Little."

The quantity of water at disposal (one-tenth of a gallon of each specimen) was not sufficient to allow of a complete analysis in each case.

The following table, however, shows the composition of the soluble salts of four specimens, two of them being from the granite, and two from the macadam pavement.

ANALYSIS of the Soluble Matter in different Specimens of Street Drainage Water.

	Grains in an Imperial Gallon.			
	Great Traffic.		Little Traffic.	
	Granite. No. 10.	Macadam. No. 6.	Granite. No. 12.	Macadam. No. 7.
Water of combination and some soluble organic matter	77.56	29.07	22.72	13.73
Silica	.51	2.81	..	..
Carbonic acid	15.84	12.23	None	None
Sulphuric acid	36.49	38.23	46.48	34.08
Lime	6.65	13.38	25.90	16.10
Magnesia	None	23.51	Trace	3.50
Oxide of iron and alumina, with a little phosphate of lime	2.58	1.25	..	..
Chloride of potassium	None	10.99	None	2.79
,, sodium	53.84	44.88	18.44	19.70
Potash	82.76	18.27	8.75	5.23
Soda	..	..	1.58	..
	276.23	194.62	123.87	95.13

It will be seen that the soluble matters of the different specimens of

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water consist of salts of potash, magnesia, lime, and soda. The quantity of sulphuric acid (in the state of sulphates of lime and potash) seems to be very little influenced either by the quality of the pavement, or the quality of the traffic; and it would seem probable that it owes its origin to the large quantities of sulphur daily thrown into the air from the coal burnt in the metropolis. This sulphur, in whatever form it might originally exist in the air, would rapidly be oxidated and brought down in tolerably equal quantity in the different streets.

It appears from the table, that the granite furnishes little or no magnesia to the water, whilst the quantity from the macadam is considerable.

On the other hand, the quantity of potash is far greatest in the water derived from the granite.

The traffic, as was before seen, has a very great influence on the quantity of the soluble salts. It seems also to influence their composition, for we find no carbonates either in the water from the granite, or that from the macadam where the traffic is little; whereas when it is great, carbonates of lime and potash are found in the water in large quantity, a circumstance which is no doubt attributable to the action of decaying organic matter on the mineral substances of the pavement.

The waters contain small quantities of salts of ammonia in solution, but their proportion was not ascertained.

The insoluble matter in the waters consists of the comminuted material of the road itself, with small fragments of straw and broken dung.

The relation between the mineral and organic portions was ascertained in three samples, and was as follows:—

	Per Cent.	Insoluble organic matter in the Gallon.
Number 5	24·00	40·39
„ 6	14·48	56·51
„ 10	38·39	220·01

The quantity of soluble salts (especially of salts of potash) in many of these samples of water is quite as great, and in some cases greater than that found in the samples of sewer-water that have been examined;* and it is open to question and further inquiry, whether the water obtained from the street-drainage of a crowded city might not often be of nearly equal value as liquid manure with the sewer-water with which it is at present allowed to mix.

Two specimens of water collected from the roofs of houses were examined; they were slightly turbid, with a black matter (soot). The following was found to be their composition:—

	Grains in the Gallon.	
	Insoluble.	Soluble.
No. 8, Albion-street, Caledonian-road, slated roof.	30	12·0
No. 9, Winchester-street, Pentonville, tiled roof	Very small	12·80

The quantity was too small for quantitative analysis, but it was ascertained that the soluble matter in both these waters was principally and almost wholly composed of sulphate of lime, having no doubt a similar origin to that found in the street-drainage water, namely, the sulphur given off in the combustion of coal. It would appear that water thus collected in London is of half the impurity and half the hardness of Thames water.

1st October, 1850.

J. THOMAS WAY.

* By Mr. Lovick's inquiries, and two analyses of sewer-water made by myself.

LETTER from THOMAS SPENCER, Esq. (of Liverpool) respecting the Mr. Spencer.
ACTION of WATER upon LEAD.

SIR, Liverpool, 9th May, 1850.

BEING requested to draw up an abstract of my opinions relative to the chemical action which ensues between different qualities of water and lead, I beg to lay the following brief paper before you.

I may premise that the views I entertain are derived from the results of numerous experiments, some of which have been made and recorded by others, but which have been subsequently repeated and verified by myself.

Another portion, however, is advanced, as far as I am aware, for the first time. I allude to those which show that the oxide of lead is dissolved by most of the salts contained in hard water.

That perfectly pure water wholly deprived of air does not oxidise lead, is admitted by all who have given attention to the subject.

This is, perhaps, better expressed when we say that "lead does not possess the power of decomposing water," and it is also more in accordance with the views of science. Water, however, is never found absolutely pure or free from air. On the contrary, it usually contains mineral, organic, and gaseous matters in solution. Sometimes one class of bodies predominate, sometimes another, but not unfrequently all three are present. Moreover, when in its purest natural state as rain, water is always mingled with the atmosphere through which it falls; hence it not unfrequently contains gaseous matters derived from smoke. For the subject under inquiry, all foreign bodies found in water must strictly speaking, be looked on as impurities, as we know that they influence the chemical action between water, lead, and air. Although air is the prime oxidizing agent, yet it is only in connexion with water that it is so; as the oxygen of perfectly dry air does not combine with lead at common temperatures. But air does not exist naturally in a perfectly dry state, but is always more or less combined with water. On the other hand, water in its natural state is never found without air. Even boiling it does not absolutely deprive it of all the air which it contains.

In pursuing the inquiry we have, therefore, to consider the effect which these bodies have upon lead when they are dissolved in water. Both practice and experiment show that air and moisture, when combined, are alone sufficient to oxidize lead, although they do not possess the power of rendering the resulting oxide soluble; *this second action being altogether due to the mineral or organic substances which the water may happen to contain.*

The first and only chemical change then, which takes place *in pure water* when in connexion with lead, is the formation of a hydrated oxide on the moist surface, say of a cistern. This chemical change is effected by the united action of air and water alone; but should the same take place *in hard water*, which on exposure it is more than equally liable to do, then the oxide will be taken up and held in chemical solution, and thus it becomes diffused throughout the volume of water. If therefore, the salts which give to water its hardness were not present, the oxide could not be held in chemical solution. Indeed, when the oxide forms in soft water, its tendency is to remain on the surface of the lead, either in that state, or, if much exposed to air, as a car-

Mr. Spencer. bonate. Should agitation or any other circumstance cause its removal, it has no power of diffusing itself chemically throughout the water, since we find that it may be separated by filtration, so that the most delicate tests are unable to detect it.

We thus arrive at two conclusions: one, that air and water jointly form an oxide which is *insoluble in soft water*; the other, that hard water and air also form this oxide, but that *in the latter it becomes soluble*. We are therefore fully justified in stating that hard water in connexion with lead is more dangerous than that which is soft.

Having thus far stated the general case, we have now to consider the circumstances which arise in practice. Although the abstract fact is generally admitted, that *perfectly pure* distilled water, totally deprived of air, does not oxidise lead, yet the question has been usually discussed as between rain-water on the one hand, and hard water derived from springs on the other. Those who have reported on the action of water on lead, as far as I can learn, have used rain-water caught within or not far from a town, for their experiments. Now rain-water not only contains a larger proportion of air than water which is taken from a surface-brook, but the rain of a town can never be said to be altogether free from fine particles of soot, as well as gaseous matter derived from the combustion of coal. Even filtration does not altogether remove these matters, as their particular taste is still perceptible.

There is therefore no doubt that, under these circumstances, slips of brightened lead become more rapidly tarnished when immersed in such water, than if in ordinarily hard or spring water. In proof of which I may state, that where experiments have been made with rain-water, caught at a distance from a town, the lead remained comparatively untarnished, as in distilled water. On the other hand, where similar experiments have been made with hard spring-water, it has been inferred, because the lead has sustained little diminution of brightness, that no oxidizing action had taken place, and therefore that hard water is less dangerous in connexion with this metal than soft water.

But the fact has been altogether overlooked, that some of the earthy salts, which give to water its hardness, have the power of dissolving this oxide as soon as formed, and therefore operate to prevent an oxide from depositing itself on the surface of the lead; thus keeping it bright, and at the same time leading to the conclusion, that it has continued unacted upon, even when the water has remained exposed to the atmosphere. Those who have observed the destructive effects of hard water on cisterns, especially in Liverpool, where the water is pre-eminently hard, but who have not studied the matter chemically, have been at a loss to account for some of the scientific opinions so much at variance with their daily observation. In a word, the closet-experimenter has usually come to the conclusion, that *soft water only* acts upon lead, while the practical observer finds that cisterns are more rapidly corroded by hard water: hence has arisen so much conflicting opinion. A little reflection, however, will render it obvious that the effects of practice can scarcely be observed by the mere immersion of slips of brightened lead into glass vessels containing either hard or soft water, and there suffering them to remain for a few weeks, perhaps only so far covered as to prevent evaporation or the accession of dust.

To have made experiments that would realise the practice, the whole circumstances of an intermittent supply ought to have been taken into account. Mr. Spencer.

It must be recollected also that, as cisterns are constructed, lead is not the only metal which has to be dealt with; there being the solder which is used for the joints. Now this substance, which is an admixture of lead and tin, will, when immersed in water along with lead, act as a distinct metal, and give rise to a voltaic action between the lead, the solder, and the water. This will cause a rapid corrosion at the joints, but it will be more or less active *in proportion to the hardness or chemical impurity of the water.*

Those who have given attention to the principles which govern electro-chemical action, can have no difficulty in understanding this, and that were the water perfectly pure, such an action could not take place.

We have next in the order of practice to take into account that intermittent filling and emptying, which so frequently expose the sides of a leaden cistern to the united action of air and moisture. This also considerably accelerates the formation of the oxide. Indeed, I believe that it tends to its production more than any of the circumstances connected with a cistern. That it is much influenced by evaporation, there can be no reasonable doubt. In proof of which we find, that where the water of a cistern is kept at the same level by constantly adding as much as is taken away, thin lead will soon be cut through *at the water-line*, or, rather, the line of evaporation. Under the same circumstances the effects produced by soft water are comparatively slight. Were lead upon roofs to be as often sprinkled with hard water as it is with rain, and taking into account the rapidity of evaporation, the duration of this metal under such circumstances would be much more limited than we know it to be.

It is the opinion of some that the earthy salts which are contained in hard water operate to prevent this metal from being diffused or oxidized. On any principles of recorded science, it is difficult to understand how a salt in solution can operate to prevent corrosion of a metal, except where it may be said to neutralize an acid. But in this instance there is no acid present; as carbonic acid, as it exists in air, can scarcely be called so, as it does not act upon lead until after the oxide has been formed.

That a neutral salt in solution can afford what, for want of a better term, might be called a catalytic protection to a metal, is so contrary to analogy, that on strictly chemical grounds it is scarcely reconcilable.

But if sulphates and silicates afford the protection they are said to do, it can only be understood on the principle that when water contains a salt in solution it becomes, for lack of room, less capable of containing another body than when purer, and this in the direct ratio of its approach to saturation.

In this sense such protection becomes strictly mechanical, and is better expressed when we say that water which contains another body in solution, necessarily possesses *less* interstitial space than when unoccupied.

On this principle we can also conceive how it is that rain-water contains more air than water which is preoccupied by mineral salts.

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Altogether independent of this, however, I find by experiment that neither the sulphates nor the silicates which are found in water have the power of dissolving oxide of lead. We are thus far positive, therefore, that the presence of these bodies, as far as lead is concerned, is much less objectionable than most of the other salts which are found in spring water.

We now arrive at the consideration of these salts of hard water which may be proved to be positively objectionable, in connexion with lead. I had been aware, from observation and experiment, that hard water not only oxidized lead when exposed to air, but that it also dissolved and consequently held such oxide in solution, but which latter property was *not* possessed by soft water. I found likewise that waters taken from different wells, and which indicated the same degree of hardness according to the scale, yet their action upon lead differed very materially; the water of one well, for instance, dissolving more oxide of lead in a given time than that taken from another: the fact being inferred from the variable discoloration of the water by sulphuretted hydrogen, which fairly indicates the quantity of oxide dissolved in a given time. I have also found that the formation of the oxide itself takes place more rapidly in some waters than in others, where the degrees of hardness are alike. It seemed, therefore, tolerably clear that this disparity must arise from the different properties of the salts contained in the waters. Nor was there much difficulty in arriving at this conclusion, as the chemical constitution of our Liverpool waters differ so considerably from each other. For example, we find that water taken from two wells, each of which shall indicate, say 18° of hardness, according to the scale laid down by Clarke, yet one of them shall contain 12 grains of magnesia to the gallon, while the other may contain only 4 or 5; but, on the other hand, the first water may contain only 5 or 6 grains of lime, and the other will then contain 12 or 13 of the same substance. Now, although in the usual acceptation of the term these waters are nearly of equal hardness, yet, it being derived from difference of chemical constitution, the action upon lead will differ materially.

It is perhaps not unworthy of remark, that in sandstone districts the spring water varies considerably in chemical constitution; even where the wells are little apart from each other.

General observations of this nature, led me to examine the salts of hard spring-water separately, to ascertain if possible which of them exerted the most power in dissolving the oxide of lead, seeing that wherever water is exposed in open leaden vessels this substance is always formed.

After making a series of experiments to ascertain this important point with the waters of various wells, the chemical constituents of which I had previously ascertained by analysis, I arrived at the following conclusions:—

First. That, as a rule, most of those salts which give to water its hardness are capable of dissolving the hydrated oxide of lead.

Secondly. That their solvent power is unequal.

It would follow, therefore, that those salts which possess the solvent power in the greatest degree must be looked on, when in connexion with lead, as the most dangerous.

After making a series of experiments I find that water which derives Mr. Spencer.
its hardness chiefly from supercarbonate of magnesia is more dangerous than water which altogether or in greater part derives its hardness from supercarbonate of lime. I find then that the following salts of hard water are capable of dissolving the hydrated oxide of lead. They are placed in the order of their solvent power, and consist of

Supercarbonate of Magnesia.

Supercarbonate of Lime.

Chloride of Sodium.

Chloride of Magnesium.

Chloride of Calcium.

As it may be necessary to verify these results by some readily made experiments requiring little chemical experience, I subjoin the following:—

Make a hydrated oxide of lead, by dropping its acetate (sugar of lead) into a solution of ammonia. The resulting powder is the oxide, and represents that which is formed by atmospheric action in water. Let it be washed until the water shows no indications of lead by sulphuretted hydrogen. A few grains of the oxide thus formed are to be put, while moist, into a bottle containing a few ounces of what is termed fluid magnesia (sold in the shops as Sir James Murray's fluid magnesia). It may be diluted with half or four or five times its bulk of water, its solvent power being in the ratio of its strength. After agitation for a few minutes let it be filtered, and when the usual tests are applied to the filtrate of magnesian water, it will be evident that the oxide of lead has been dissolved.

This fluid magnesia is chemically identical with the supercarbonate of magnesia found in hard water; the simple carbonate being in both cases held in solution by carbonic acid. This experiment shows the solvent power of magnesia when found in hard water.

Another experiment may be made to prove that the supercarbonate of lime also dissolves this oxide. To do so it is only necessary to repeat the foregoing one, but substituting carbonate of lime-water for the magnesian. That sold in the shops as "Carrara Water" (being carbonate of lime held in solution by carbonic acid) precisely represents the carbonate of lime which is found in hard water.

Upon applying the test as before, it will be found that this also dissolves the oxide, but less so than in the preceding instance.

The free carbonic acid, which is to be found in these artificial waters, does not contribute to these results, for should it combine with the oxide the resulting carbonate is insoluble.

An experiment may also be made with common salt (chloride of sodium) dissolved in water, or with chloride of calcium or of magnesium, and, when the test is applied, the oxide will be found in chemical solution; but in these cases sparingly.

The salts which I have enumerated are contained more or less in all potable hard waters. When, therefore, it can be satisfactorily proved that their action upon the oxide of lead is such as I have found it to be, the system of storing up water in open leaden vessels ought to be discontinued. With us, in Liverpool, we have hard waters in public use which contain as much as from 20 to 40 grains of

Mr. Spencer. these substances to the gallon, while many private wells contain from 100 to 200 grains in the same quantity of water.

I am fully convinced that the proportion of air which is naturally contained in either hard or soft water contributes little practically to the formation of either the oxide or carbonate of lead. Where I have made experiments with fresh-caught soft water, and therefore containing its full proportion of air, little or no action has been observed on slips of lead when immersed in it. It is important, however, to bear in mind, that this has only been so when I have taken the precaution to cover the surface of the water with oil, thus rendering further access of air from the atmosphere impossible. Where I have neglected to adopt this precaution, the oxide formed, be the water hard or soft.

I have not found that others have had recourse to this plan of excluding the air during their experiments, otherwise I think it probable that it would have had some influence in modifying their results. I find also, upon much inquiry, that, wherever a constant supply of water is given, little or no signs of corrosion are manifested upon the interior of the leaden service-pipes, they being kept always full, and necessarily free from air.

It is well known that a highly comminuted powder of metallic lead may be made to become mechanically diffused by agitation throughout either hard or soft water: and while in this state it most readily attracts oxygen.

Where I have agitated pieces of lead in water deprived as much as possible of air, the bottles being also perfectly filled with water, this powder has not been formed so copiously. That the atmosphere exercises a main influence in diffusing lead, will be further evident, when we take into consideration that this metal is to some extent volatile, it being known to impart a peculiar odour, which is abundantly evident upon its being handled.

In conclusion, I may state generally that I have not been able to detect lead in ordinarily soft water which had passed through pipes which have been kept always full, and consequently free from atmospheric exposure.

ABSTRACT OF THE FOREGOING.

When lead and soft water act upon each other in perfectly close vessels or pipes, it is due in all ordinary cases to that air which water may be said to contain naturally.

When this action takes place, it never extends beyond a slight formation of a low oxide of lead, *which is insoluble in soft water.*

Where an oxide is extensively formed, it is due to the extraneous absorption of air from the atmosphere, but which can only occur when the surface of the water is exposed, as it is in a cistern.

We thus deduce, as a direct consequence, that leaden pipes, when kept charged with water, are little objectionable, inasmuch as they are then comparatively free from atmospheric action. In practice it is also found that leaden service-pipes which are kept full, as in a constant supply they must be, exhibit little or no traces of oxidation after long use.

As it is obviously impracticable to keep cisterns always full, as well

as it is to keep them free from the operation of the atmosphere, it would therefore follow that their use is highly objectionable for either hard or soft water. Mr. Spencer.

The following applies more particularly to *hard water*.

When hard water is exposed to the atmosphere in an open leaden cistern, the hydrated oxide of lead and its carbonate are more rapidly formed than in soft water; the evaporative action upon the moist sides of the cistern, much promoting the formation of these substances.

In the vicinity of the soldered parts of a cistern, however, the oxide is still more rapidly produced, in consequence of the voltaic action which takes place where dissimilar metals are present, the superior electrical conductive power of *hard water* promoting the action. Hence it is that cisterns which contain hard water corrode so rapidly at the joints.

When decayed organic matters accidentally fall into a cistern, hard water also acts more injuriously than soft. It is well known that water holding any substance in solution is more easily decomposed than purer water. In such a case water is decomposed, and carburetted hydrogen is given off, whilst the resulting oxygen enters into combination with the lead. Holes are thus frequently found at the bottom of cisterns where such matters have rested.

When oxide of lead is formed in commonly pure or soft water, it *is not soluble, yet hard water is capable of dissolving it*.

It becomes thus diffused chemically throughout the volume of water. It may therefore be said, as regards lead, that water is dangerous in the ratio of its hardness.

All hard waters, however, are not equally capable of dissolving this oxide, their solvent power depending on the character of the salts which they contain. For instance, water which contains carbonate of magnesia in solution has a higher solvent power than that which contains an equal amount of carbonate of lime. In like manner chloride of sodium (common salt) dissolves this oxide of lead more readily than the chlorides of magnesium or calcium.

I have the honour to be, Sir,

Your very obedient servant,

Henry Austin, Esq.,
Gwydyr-House, Whitehall.

THOMAS SPENCER.

Liverpool, 9th May, 1850.

LEAD PIPES.

“THE subject of lead pipes has lately attracted much attention in Boston, where the matter was fully investigated previous to their adoption, in distributing the Cochituate water, recently introduced into that city. The result of the investigations, conducted under the superintendence of Professor Horsford, has recently been published in the Report of the Water Commissioners, and sets the question, in my opinion, finally at rest. From this Report it appears that no evidence of disease from lead has yet been detected in the cities of London and Paris, from the use of the hydrant water, although that material is in universal use in both of these cities as service-pipes.” Dr. Wynne.

“Professor Hare of Philadelphia, Professor M'Naughton of Albany, and Dr. Bruismade of Troy, New York, all bear testimony to the

Dr. Wynne. — same fact, although the lead for service-pipes has long been used in each of these towns. Professor Hubbard of Dartmouth College, states that the village has been supplied for 26 years with water conveyed two miles in lead pipes, and that he has never heard of a case of lead poisoning from its use."

"Dr. Dana, in an Appendix to his Translation of the Work of M. Tanquerel, on lead diseases, recently published, has furnished a very strong argument against the use of lead pipe, which, in the absence of the positive testimony furnished by the Boston Water Commissioners' Report, might go far towards banishing it from use. In his remarks on the specimens of Baltimore and James River pipes examined by him, he says that he observed slight cribriform erosion, and adds, "But this is evidence that so slight an action could not have been sufficient to produce erosion in a few days. It may be inferred to have gone on for years." Since the appearance of Dr. Dana's work, I have examined numerous specimens of lead pipe, which has been long in use in Baltimore, some upwards of 25 years; and although I have anxiously sought for some evidence of the slight erosion mentioned in Dr. Dana's work, I have not, in any instance, been able to detect it. I therefore conclude that the erosion in the specimen examined by him was due rather to some original defect in the texture of the metal, than in the action of the water upon it. The interior of the pipe was always found thickly coated with an earthy deposit, which adhered with such tenacity as to require considerable force and much washing to remove it, and in my judgment formed a considerable protection to the water against the action of the lead, admitting its capacity to unite with the water which did not appear, from any evidence, furnished by the pipe itself.

"I have met with several cases of disease from lead amongst workmen engaged in its manufacture since my residence here; but have never observed any lead disease which might be attributable to the use of the hydrant water. Within a few weeks, the pipe of the hydrant attached to my own residence was removed, and its place supplied by a new one at least 60 feet in length, and although the water was used soon after, I could not learn that any member of my family experienced the slightest injury from it."—*From a Report on the Sanitary Condition of Baltimore, by James Wynne, M.D., published by the American Medical Association.*

*Thomas Clark, Esq., M.D., Professor of Chemistry in Marischal College, University of Aberdeen, examined.**

Professor
Clark, M.D.

1. You are professor of chemistry at Aberdeen?—I am.
2. It is stated that you have paid much attention to the quality of water in the metropolis and other parts of the United Kingdom; is that the case?—I have paid attention to this subject for many years, partly from the interest to society that belongs to the subject of the supply of towns and manufactories with good and wholesome water,

* This evidence, which was originally taken on the 3rd June, 1843, by the Commissioners of Inquiry into the State of Large Towns and Populous Districts, has been revised by the witness. The principal additions are distinguished by brackets.

and partly also from the interest that belongs to the subject as a branch of knowledge, and a part of my duty in teaching pupils at the college. I have examined very particularly the qualities of the waters most in use in the metropolis, and in several other towns throughout the United Kingdom, but not the waters of a great many towns.

3. What are the various kinds of impurities found in water?—These are of various kinds. There are the mineral or saline, the vegetable, the animal, and also the mechanical impurities.

4. What kind of impurities are separated by filtration?—Only the mechanical. (See Q. 41, 44, 45, 48, 52, 64, 65.)

5. You have stated that the water usually contains saline impurities; of what do those consist?—The most material are earthy salts, that is, salts of lime, and salts of magnesia. I call the earthy salts the most material, because it is the presence of earthy salts that gives rise to hardness. There is also usually present common salt, and sometimes bicarbonates of soda and of potash; but none of these affect the hardness of water. The most important portion of the earthy salts may be reckoned the bicarbonate of lime. The whole salts present, whether earthy or not, may be distinguished into two parts, according as they are neutral to test paper, or alkaline to test paper, (See Q. 18.) the neutral portion and the unneutralized portion. The unneutralized portion consists entirely of bicarbonates, those of lime and of magnesia, which are the earthy bicarbonates, and in some waters those of potash and soda, which are the alkaline bicarbonates. The neutral portion consists of the neutral salts of earths and alkalies, such as gypsum and common salt. Salts of iron occur also occasionally in waters that are in use. Such salts impart an inky taste to the water, and they give a yellowish tint to linen that is washed by the water containing them. They, too, produce hardness.

6. What are all the impurities in water that give rise to the quality commonly termed hardness?—The earthy salts and iron salts, if they be present; certainly earthy salts are the principal cause. I have had occasion to observe recently that there is in a few waters a minor cause, carbonic acid, where it exists in excess; that is, in a greater quantity than is sufficient to form the bicarbonates present.

7. Does boiling, exposure to the air, or filtration, affect the hardness of water?—Filtering does not affect the hardness of water. Exposure to the air softens waters so far as they are hardened by carbonic acid, and it very slightly affects waters that are hard on account of earthy bicarbonates. Boiling affects the hardness of waters in some cases; it does not affect it at all in others. Boiling softens very materially such water as contains earthy bicarbonates, by decomposing them; but so far as the earthy salts are neutral, it does not affect the hardness at all. As the operation of boiling is usually conducted, indeed, according as the hardness is owing to an unneutralized earthy salt or to a neutral earthy salt, the effect of boiling may be the reverse; that is to say, if you boil water containing an unneutralized earthy salt, you soften it; if you boil water containing a neutral earthy salt, you harden it, in case you concentrate the water by letting part of the water, pure and perfectly soft, escape in the form of steam. Therefore it is a most material point in the treating of water to be aware, not only of the amount of its hardness, but how far that hardness is due to neutral earthy salts, and how far to unneutralized earthy salts.

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8. Is not there a testing process of easy application by which the hardness can be measured, and by which the hardness affected by boiling can be distinguished from that not so affected?—There is a very easy and most accurate process for trying the hardness of water, that I had occasion to contrive above two years ago. I need not go into the details of that before the Commissioners, because the details of the method are printed in a specification to a patent of mine, dated the 8th of March, 1841. The specification is printed in the Repertory of Patent Inventions for October, 1841.* All I need state at present in reference to that method is, that you can try by it the hardness of water in the course of less than an hour. The method I take of expressing the hardness of water is this, 16° of hardness means the hardness that would be caused by the presence of 16 grains of chalk per gallon; 10° of hardness, the hardness that would be caused by the presence of 10 grains of chalk per gallon. In the application of this process, it is of no consequence in what state of combination the earthy salts be. Whether the lime or other earth present be in the state of bicarbonate, or in the state of a neutral salt, or in both states, the test would indicate precisely the same degree of hardness in any two waters, if the quantity of earth, or of basis of the earth in each, were present in the same proportion. There is also a test given in the process alluded to for distinguishing so much of the earthy salts present as are neutral, from so much of them as are unneutralized, that is alkaline, or in the state of bicarbonates. (See Q. 25.)

9. It is generally admitted that hard water (See Q. 12, 31.) is unfit for the purposes of washing and of cooking?—With regard to cooking, perhaps the most important material is tea. I have been very desirous of making a series of experiments on waters of known degrees of hardness upon a given average of tea, with the assistance of some gentleman experienced in the tasting of teas for commercial purposes. My health has heretofore prevented me from making any more than merely preliminary experiments. From these it appeared that hard water was very unfit for the purpose of infusing tea. In making use of a series of waters at 4° , 8° , 12° , 16° of hardness, the strength of the infusion, as manifested by the depth of colour produced, was evidently in a series, such that each infusion could be sensibly distinguished from the one next to it, above or below, the hardest water giving the least depth of colour, and the softest water the greatest. At 4° of hardness the infusion was transparent with no sensible muddiness; at 6° the transparency of the infusion began to be injured; at 12° there was a distinct muddiness; at 16° this muddiness had become very decided, and above 16° it was disgusting. No such muddiness appeared with any of the waters after pouring off the first infusion and making a second. With regard again to depth of colour, it is very worthy of remark that, whereas the greatest depth was observed in the first infusion in the softest water, and the least depth in the hardest, now, in the second infusion the same thing was observed again, with this difference, that in the harder waters the depth of colour was proportionally still less; not only absolutely less, as might be expected, but relatively less. In making these experiments, about half an ounce of tea was made use of with a pint of boil-

* Republished by J. J. Griffin and Co., Baker-street, who also prepare the apparatus and tests necessary.

ing water, so that you will understand the result, if you suppose in each of two similar teapots half an ounce of tea be put, and over each a pint of boiling water, but in the one case at 4° hardness, and in the other case at 16° , the infusion at 4° will turn out much stronger than the infusion at 16° ; the infusion at 4° will be transparent; the infusion at 16° will be offensively muddy. But supposing you pour off the first infusion and make a second infusion, then the second infusion at 4° will be a little weaker in colour than the first infusion at 4° , while the second infusion at 16° will be of a still proportionally weaker colour than the first infusion at 16° . In short, hard water is bad for a first infusion, still worse for a second. The only way of making an infusion of tea with waters at 8° , 12° , or 16° , equally strong with an infusion by water at 4° , is to increase in each case materially the quantity of tea infused. Sub-carbonate of soda in crystals may be made use of in very small quantities in order to soften the water and make it fitter for the purpose of infusing tea; it produces this effect by decomposing the earthy salts present; but if made use of in any proportion above what will exactly decompose the earthy salts present, the excess may indeed deepen the colour of the infusion—by dissolving some coloured vegetable extract, such as pure water, would not dissolve, but it will infallibly injure the fine flavour of the tea to all persons not accustomed to the taste of soda in their tea.

10. Is there any other respect in which the hardness of water is injurious to the inhabitants of towns?—The fur (which is an incrustation chiefly of chalk) that forms when waters that are rendered hard by the presence of an earthy bicarbonate are boiled, is at least exceedingly inconvenient. In all the manufactories in large towns, so far as you have got such a water, the bottoms of your steam-engine boilers become incrustated very soon. This requires the steam-engine boilers to be cleaned out much oftener; and I think that the fur formed by such a water is the most frequent cause of explosion in steam-boilers, and most materially increases that risk; at the same time that it causes the wear and tear of them to be much greater. Fur likewise very much increases the risk of explosion in locomotive engines. I think also that fur must be very inconvenient, whenever you attempt to heat by water-pipes, because, immediately on employing such water the pipes get coated internally with earthy matter, in some cases to a very material thickness, so as to fill up the metallic pipe with an earthy incrustation, and prevent the heat from passing through. I have known pipes connected with boilers, in a large brewery in London, filled up throughout the whole length by a solid incrustation in six months.

11. What conditions in water do you think fit it best for being an agreeable beverage?—In the first place, the particular kind of water that is agreeable is dependent very much upon the habits of the drinker. If you are accustomed, exclusively, for a certain time, to a hard water, you acquire a liking for hard water; if to a soft, you acquire a liking for soft, just as habit varies the taste for other beverages. Putting the effect of habit out of the question, one circumstance, which I think is most material for water to be agreeable, is the temperature, especially in warm weather, when good water to drink is most prized. It has been supposed that water, such as is used in this town, being exposed in a

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room for some time loses a portion of carbonic acid. Everybody knows that water which has been in a sitting-room is not so agreeable as when first drawn; but I am quite satisfied that whatever be the cause of its becoming less agreeable, it is not in general the loss of carbonic acid; for I am quite certain that there is not in any of the river waters about London an excess of carbonic acid over and above what is necessary to form the bicarbonates present. I think the main point affecting the agreeableness of water, as far as I have seen in examining water accounted agreeable in this town, is the temperature. In summer time you have the spring waters, when fresh drawn, cool. You can have other waters rendered more agreeable than they are in summer time, if you take the pains of cooling them to the same degree as the spring water. You must not have the water too cool either, otherwise it is unpleasant, as well as unsafe to drink, but an average temperature of the climate, which is about 50° Fahrenheit, is a very agreeable temperature for water. So far as the presence of carbonic acid will add to the agreeableness of water, and it does so to many tastes, that quality can be imparted to any water by the simple expedient of adding a very small proportion of soda water. No doubt there are circumstances that make water offensive, particularly the presence of vegetable matter in a state of change, whether that matter be undergoing putrefaction, or a vegetating process of any kind. In any such case I reckon the water polluted, and the taste is entirely tainted and offensive, especially to persons not accustomed to drink such water. But if water be free from taint, be of a sufficiently low temperature, and be not absolutely deprived of wholesome gaseous matter, I think it has most of the qualities proper to render it agreeable, allowing for the variations in taste that are acquired. If all these conditions contributing to the agreeableness of water exist, then I think that such persons as have been accustomed to drink various kinds of water will be found to prefer a water containing little saline matter to another containing much; if a contrary impression has been usually entertained, it is owing to some of the other circumstances affecting agreeableness having been overlooked. At the present time, in order to obtain good water for drinking in London, I would recommend the use of water that has been boiled, cooled, treated with carbonic acid by the addition of a little soda water, and then iced to a temperature rather under 50° Fahrenheit; but all this pains to obtain good water cannot be taken by the poor, or even by the generality of families in the middle classes. I think that if the means were taken by the existing water companies, water only requiring to be a little cooled in the heat of summer to be fit for drinking by all classes, might be supplied, and should.

12. What general circumstances would regulate you in the choice of a water for the supply of a town?—There is a great variety of circumstances to be taken into account in selecting a water for the use of a town. Supposing we had the choice of several waters, there is no single quality of a water to which I would attach more importance than softness, because, although a soft water may not happen in other respects to be agreeable for drinking, yet it very often happens that water agreeable enough for drinking is supplied by wells in the town. The proportion of the whole supply of water used by the inhabitants for drinking is exceedingly small; for this reason, the mere agreeable-

ness of the water as a drink, I would not reckon a high point. With regard to the softness of water, this quality is of importance, not merely for the saving of soap to households, for the agreeableness of washing at the toilet, for the agreeableness and utility of bathing, which I account a most important practice for promoting the health of the inhabitants of a town, but also in respect of the wear and tear of linen due to hard water. Such wear and tear comes to be a very large item of expense to the inhabitants of a town. The inhabitants of London are probably not aware so much as visitors from the country are, of the amount of destruction to clothes in consequence of the hardness of the water, and the use of soda in order to get rid of the hardness. I remember an occasion, which I may mention, where the amount of wear and tear was brought out in a very conspicuous manner. Two young men, brothers, in Glasgow, were put into counting-houses, one in London and the other in Glasgow. They had each a similar assortment of shirts given to them. Some time after, when the brother in London came back on a visit to Glasgow, the lady of the house pointed out, to the wonder of her female friends, the difference there was in the wear of the shirts of the two brothers, that had been given at the same time; those that had undergone the London washing were so much more worn than the others which had been washed at Glasgow. Yet I can state from experience that linen gets soiled from the atmosphere rather more readily in Glasgow than in London.

13. What was the difference in the hardness of the water?—The hardness of the Glasgow water was about 4° and that of the London about 12° .

14. It is to be assumed that a great saving would accrue to a town by using soft water, in the article of soap, for instance?—Not only in the article of soap, but probably much more in the saving of the wear and tear of clothes. The hard water has a tendency to discourage washing of clothes among the poorer classes, and to bring on them greater expense in clothes. This consideration bears very closely on the clothing of women and children; and I rather think, that if manufacturers of the articles of clothing worn by women and children, in a district supplied with hard water—this very London, for example—were consulted, it would appear that they are obliged to supply articles of such dark dyes as will not let the dirtiness be seen. Now to substitute the art of concealing dirt for a habit of cleanliness, not only is unfavourable to health and comfort, but is unfriendly to a decent self-respect; yet an observant eye cast on the women and children of the poorer inhabitants of London, may discover that such has been the result here.*

15. What degree of hardness do you think would render water unfit for the use of a town?—That is a question that cannot be answered definitely. Of the waters used in towns, I am not acquainted with a great number. The pipe water that I am accustomed to use at home stands at only 1° of hardness; meaning thereby, as was mentioned before,

* “ We returned to the beautiful St. James’s Park, went through the Green Park to Hyde Park, then into Kensington Gardens, and back to Hyde Park, favoured by the weather, and cheered by the freshness of a spring. * * * * * All the women of the lower classes were very simply dressed, *chiefly in black or dark colours*, but few remarkable for beauty.”—See Raumer’s “England in 1835,” vol. i., p. 212.

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(see Q. 8) as much hardness as the presence of one grain of chalk per gallon would produce. The pipe waters of London range between 11° and 16° , according to my experience; I mean the waters of the companies. The pipe water of Manchester is 12° of hardness; the water of Glasgow is $4\frac{1}{2}^{\circ}$ of hardness; of Edinburgh about 5° ; the Newcastle-upon-Tyne Company's water is nearly the same, according to a single trial, taken however after much rain. With regard to the general question, what degree of hardness should unfit a water for being used, that is manifestly a question that cannot be answered absolutely. The softest water that can be got in sufficient quantity *in the district*, I hold to be in general the one that ought to be preferred, other circumstances being favourable. I think, from observing (and I have given a good deal of attention to such observations on the action of water) that a water ceases to be agreeable for washing when it is above 4° or 5° of hardness; I have already mentioned that a harder water than this is very objectionable for the making of tea. (See Q. 9.) Water, when it is above 16° , I would say becomes excessively inconvenient for washing. There are some hard waters more objectionable than others, even of the same degree of hardness, on account of the curdy or clotty character of the earthy soap produced in them. This clotty character renders such waters particularly unfit for the washing of clothes. Now, I find this character of hard water to be due to the presence of a little magnesian salts. And it is a very curious fact, that if the hardness of the water be above 10° or 12° , owing to lime salts, a few degrees of hardening matter in the form of magnesian salts may be added to the water, without its hardness being increased; but then the curdling power of the water is very much increased. There are, however, waters much harder than 16° in use, and those, undoubtedly, must be accounted fit waters for use, provided they are the softest that can be got in the district.

16. To what district do you refer, where there are very hard waters? —Paris might be mentioned as one instance. Many towns in England also are unfortunately supplied with harder water than 16° .

17. The pipes or leaden cisterns are sometimes corroded by water, what is the particular impurity which occasions that corrosion?—I think both leaden cisterns and pipes, and iron pipes, are corroded occasionally by water. This is a most important topic, because it has happened in some places that a water has been selected for the supply of the inhabitants, and an expense of erecting water-works gone into, and corrosion quite unexpectedly has been the result. A variety of investigations have been made as to the cause of this important objection to some waters. In considering published investigations and some observations that I have made upon the subject, I should be disposed to say, that chemists are not prepared at present to speak with much confidence as to the cause. My present impression, and indeed the prevailing impression, is, that the corrosion is due to free carbonic acid. It is well known that distilled water acts very readily upon lead. The cause of this action I apprehend to be the remarkable power that distilled water, compared with ordinary water, has of dissolving free carbonic acid.

18. By free carbonic acid you mean carbonic acid above what is necessary to form bicarbonate with the other salts?—Yes; I would add, however, that I believe that carbonic acid in excess will be found most

frequently where there is either no bicarbonate, or next to no bicarbonate present. If I obtain a water for examination, the first point I look to is, whether this water has an alkaline action; that is, whether it contains any bicarbonate. This is done by litmus test-paper. If the test-paper is not rendered of a blue tint by the water, so as to show an alkaline salt present, the chance is, that the test-paper will show, and very explicitly, the presence of carbonic acid, by the redness produced upon it. There is one water of this description supplied to the hospital at Bagshot, where, according to my information, for I have not inspected the case, a mile of iron pipes were corroded in a remarkably short time. This water as it came from the spring had a considerable excess of carbonic acid, and stood about 6° hardness; when freed from this excess it stood rather under 3° . The principal peculiarity I have as yet been able to observe in the water is, the almost entire absence of bicarbonate, and I have also observed the presence of free carbonic acid to be very frequent in waters that contain very little, if any, bicarbonate. In general, an alkaline water will not act upon lead or upon iron. But perhaps I should not say in general, for I have not examined a sufficient number of cases to lay down a general rule; but there is ground for suspecting that such an action will ensue, if you find in the water a very moderate degree of hardness and no alkalinity, together with an excess of carbonic acid. In making these statements I would still repeat that I do not consider myself entitled to speak with great confidence as to the cause of the corrosion of pipes in every case. (See Q. 71, 72.)

[At the time of answering the foregoing questions respecting the action of water upon lead pipes, I had not had the opportunity of examining any water that had been contaminated by lead pipes; but in a few days after, an opportunity occurred. Some of the Bagshot water alluded to had poisoned some of the Queen's hounds, and brought on *colica pictonum* on one of the huntsmen. Through the kindness of Sir James Clark, I obtained a specimen of this water, and in a few days came to the unexpected result that filtration would separate the lead. Thus a very simple practical means for separating lead, wherever it contaminates water, was discovered. On the 5th August, the same year (1843), being about to leave London, I left a memorandum with Sir James Clark, that I was ready to provide against the ill effects of the lead, if applied to by any authority connected with the palaces. No application was made to me. But the process came into practical use in spring 1844. At a marine villa of Lord Aberdeen's, some of the servants suffered in health from lead in water derived from pipes. Sand filters were put up under my direction at this villa, and subsequently at Haddo House. On making inquiry recently, at his Lordship's agent, in Aberdeen, I learn that the filters have been in use ever since, and that the waters have been tested from time to time, without any lead having been discovered in them. I have been told indeed, that so satisfied has Lord Aberdeen been with the result, that on hearing of the Count de Neuilly's family at Claremont, being troubled with lead in the water, he wrote recommending the same process being tried there; and from general rumour I had previously heard that the process had been adopted there. I hope I may be excused for entering into such details, for the indication they afford of the practical value

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of the process which has been adopted in the public service, without the merit of the inventor having been publicly recognised or acknowledged.

I hold it in all cases to be dangerous to allow water to pass through any considerable length of lead pipes, or to allow water to remain for a long time even in short pipes. In the case of the marine villa before alluded to, the water came a considerable distance through lead pipes; I suppose above a quarter of a mile. The water in Aberdeen is brought from the iron mains in the streets, into the houses by means of lead pipes; and in general without any disadvantage, because the supply from the pipes is constant, and the use of the stop-cock very frequent in a family; but in my class-rooms and laboratory I find that whenever a pipe has been out of use for a few days, the water taken from it affords a trace of lead, which disappears when the water has been allowed to run briskly from the stopcock for a few minutes.]

19. Under what circumstances does chalk, or carbonate of lime, dissolve in water?—The solvent of chalk in water, as it commonly occurs, is carbonic acid; and the chalk is present as bicarbonate of lime; and in the rivers that supply water to London, I have not yet found more carbonic acid than is required to form such a bicarbonate. Indeed, there is a circumstance that shows manifestly that a received idea that river water contains free or uncombined carbonic acid, is not correct. You cannot keep exposed to the air a water, such as that of the Thames, for a few days, but a small deposit of chalk will occur. The first occurrence of that deposit is a proof that there cannot be present any excess of carbonic acid. Besides this, I have repeatedly ascertained by conclusive experiments carefully performed, that the river waters about London do not contain any sensible excess of carbonic acid.

20. Can you state the quantity of carbonate of lime, or the degrees of hardness of various known waters, and the degree to which they may be softened by the application of artificial means?—I shall lay before the Commissioners some statements relative to the waters of the metropolis. Take the New River. In the middle of May, 1841, I found in the New River $13\frac{2}{10}^{\circ}$ of hardness per gallon.

21. From what part had you the water of the New River taken when you made the experiment?—This particular specimen was taken out of the New River itself; it was several gallons, probably from 20 to 30, sent to me to Aberdeen for the purpose of subjecting it to experiments. The next is the result of a great variety of trials I made from day to day of the New River water, collected by me while in town, from the pipes, taking them from various places, and finding no material difference. At the beginning of August, the same year, I found the hardness 12° .

22. Those were all New River waters?—Yes. The Thames in the middle of May, 1841, I found $14\frac{4}{10}^{\circ}$ of hardness; this was a large specimen taken opposite Mortlake.

23. Do you know what was the state of the tide at the time it was taken?—I cannot answer particularly, but I remember the collection was committed to a very careful gentleman, with all the precautions that I thought at the time necessary; I do not remember what they were at this moment. I believe I bade him take the specimen imme-

diately after the turn of the tide. The river at Mortlake is above the influence of the London sewerage. In the beginning of August, from a very great variety of trials that I made from the waters collected from various pipes in town, I found the hardness of the Thames water $11\frac{8}{10}^{\circ}$. The East London Company's water was $16\frac{1}{10}^{\circ}$ in the middle of May, 1841. This was a large specimen, which the engineer, Mr. Wicksteed, was good enough to forward to me to Aberdeen, at my request. The same company's water, taken from the pipes at the beginning of August, was $14\frac{1}{10}^{\circ}$ on an average, in a variety of trials.

24. The degrees of hardness will vary at different times, one or more?—The variation here, I take not to be due to the method of testing the specimens, but to the state of the weather, and also to lengthened exposure, which probably softens water two or three degrees.

25. Have you notes of the hardness of any of the waters on the Surrey side?—On the 11th of August, 1841, the Vauxhall Company's water was $13\frac{5}{10}^{\circ}$.

26. How do you distinguish what is due to neutral earthy salts, and what to alkaline earthy salts?—By the soap test referred to (See Q. 8.), the total hardness can be ascertained, that is, the hardness due both to neutral and to alkaline earthy salts. Next by the test acid, which is described in the specification referred to, we can distinguish the portion of the hardness that is due to alkaline earthy salts; for instance, East London water, collected on the 14th of May, 1841, is of hardness $16\frac{1}{10}^{\circ}$; it is of alkalinity $15\frac{6}{10}^{\circ}$; that is, it requires as much acid to neutralise its alkalinity as $15\frac{6}{10}$ grains of chalk per gallon would require; the difference, $\frac{5}{10}^{\circ}$ is the utmost quantity that can be due to neutral earthy salts. The Thames water and the New River water may in general be reckoned 12° of hardness; the alkalinity in the London pipe waters almost always comes within 1° of the hardness, whereas the Manchester pipe water stands 12° of hardness, while its alkalinity, according to my recollection, is only 7° . Hence, in the Thames or the New River water, no more than 11° can be regarded as the hardness due to alkaline earthy salts, and no more than 7° as the hardness due to alkaline earthy salts in the Manchester water. On boiling the Thames water, therefore, you soften only by acting on 11° of hardness, and on boiling the Manchester water you soften only by acting on 7° of hardness.

27. It is understood that you took out a patent for purifying water, by removing the carbonic acid which holds the earthy carbonates in solution; will you describe the general nature of your invention?—I beg the permission of the Commissioners to read the following extract, containing an outline of the process:—"To understand the nature of the process, it will be necessary to advert, in a general way, to a few long-known chemical properties of the familiar substance, chalk; for chalk at once forms the bulk of the chemical impurity that the process will separate from water, and is the material whence the ingredient for effecting the separation will be obtained. In water, chalk is almost or altogether insoluble, but it may be rendered soluble by either of two processes of a very opposite kind. When burned, as in a kiln, chalk loses weight. If dry and pure, only nine ounces will remain out of a pound of 16 ounces. These nine ounces will be soluble in water, but

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they will require not less than 40 gallons of water for entire solution. Burnt chalk is called quick lime, and water holding quick-lime in solution is called lime-water. The solution thus named is perfectly clear and colourless. The seven ounces lost by a pound of chalk on being burned consist of carbonic acid gas; that gas which, being dissolved under compression by water, forms what is called soda-water. The other mode of rendering chalk soluble in water is nearly the reverse. In the former mode, a pound of pure chalk becomes dissolved in water in consequence of losing seven ounces of carbonic acid. To dissolve in the second mode, not only must the pound of chalk not lose the seven ounces of carbonic acid that it contains, but it must combine with seven additional ounces of that acid. In such a state of combination chalk exists in the waters of London, dissolved, invisible, and colourless, like salt in water. A pound of chalk, dissolved in 560 gallons of water by seven ounces of carbonic acid, would form a solution not sensibly different, in ordinary use, from the filtered water of the Thames, in the average state of that river. Chalk, which chemists call carbonate of lime, becomes what they call bicarbonate of lime, when it is dissolved in water by carbonic acid. Any lime-water may be mixed with another, and any solution of bicarbonate of lime with another, without any change being produced. The clearness of the mixed solutions would be undisturbed. Not so, however, if lime-water be mixed with a solution of bicarbonate of lime. Very soon a haziness appears; this deepens into a whiteness, and the mixture soon acquires the appearance of a well-mixed whitewash. When the white matter ceases to be produced it subsides, and, in process of time, leaves the water above perfectly clear. The subsided matter is nothing but chalk. What occurs in this operation will be understood if we suppose that one pound of chalk, after being burned to nine ounces of quicklime, is dissolved, so as to form 40 gallons of lime-water; that another pound is dissolved by seven ounces of extra carbonic acid, so as to form 560 gallons of a solution of bicarbonate of lime; and that the two solutions are mixed, making up together 600 gallons. The nine ounces of quicklime from the one pound of chalk, unite with the seven extra ounces of carbonic acid that hold the other pound of chalk in solution. These nine ounces of quicklime and seven ounces of carbonic acid form 16 ounces, that is, one pound of chalk, which being insoluble in water becomes visible at the same time that the other pound of chalk, being deprived of the extra seven ounces of carbonic acid that kept it in solution, reappears. Both pounds of chalk will be found at the bottom after subsidence. The 600 gallons of water will remain above, clear and colourless, without holding in solution any sensible quantity either of quicklime or of bicarbonate of lime. The weight of chalk separated from the whole waters of the several Companies, estimated at 40 millions of imperial gallons, would be about 24 tons a-day, or 9,000 tons a-year. Here the weight stated refers to matter such as no filter can separate, and it does not include any of the precipitated chalk that has for its basis the lime added to the water in the form of lime water. Taking both together, the chalk that falls down would amount to 55 tons a-day, or 20,000 tons a-year. As far as I have been able to ascertain, the cost of the burnt chalk required for all the water Companies in the metropolis would be 10*l.* a-day. Against this cost may come

to be deducted the value of the 55 tons a-day of deposited chalk, which cannot but be available for some useful purposes. Being burned it would afford lime of improved quality for mortar, and without being burned it might answer as an ingredient of compost manures for clay soils. At the least, the expense of the burned chalk would be reduced to the cost of burning." *

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28. Can you give the results as to the degrees of hardness and alkalinity removed by the application of your process?—In the case of the East London water, I found the hardness $16\frac{1}{10}^{\circ}$, the alkalinity $15\frac{6}{10}^{\circ}$. It may be interesting to mention, that having kept the water for a long time in open vessels in a large laboratory, the hardness fell to $15\frac{4}{10}^{\circ}$. By mixing the water of $16\frac{1}{10}^{\circ}$ of hardness with lime-water, in the proportion of four bulks of lime-water to 44 of the original water, I found the hardness reduced to $4\frac{1}{10}^{\circ}$. In another trial, in the proportion of 4 to 45, the hardness became 4° . In subsequent trials, when the hardness of the water was 15° , I found the purified 4° ; when the hardness was $14\frac{2}{10}^{\circ}$, the purified was 4° . In one case, when the hardness was $14\frac{4}{10}^{\circ}$, the purified was $3\frac{8}{10}^{\circ}$. The general result was 4° of hardness in the purified East London water. Connected with this water, I may mention that all water holding carbonate of lime is softened by prolonged boiling; there is a misapprehension, however, in regard to the effect of boiling; a short boiling has very little effect indeed in softening water; when you subject water to even a sharp boiling, under the most favourable circumstances, I find two hours and three quarters, or three hours, necessary for decomposing all the bicarbonate of lime, precautions being taken to prevent any evaporation of water in the form of steam. By boiling, this water was reduced to $3\frac{7}{10}^{\circ}$. In the case of the New River water the hardness was $13\frac{2}{10}^{\circ}$, the alkalinity was $12\frac{5}{10}^{\circ}$; this purified by lime-water, in the proportion of 3 to 40, was reduced to $3\frac{7}{10}^{\circ}$ of hardness; by prolonged boiling it was reduced to $3\frac{6}{10}^{\circ}$ of hardness. I got another specimen of New River water, $11\frac{6}{10}^{\circ}$, which, by using the proportion of 1 of lime-water to $14\frac{5}{10}^{\circ}$ of the water, was reduced to the hardness of $2\frac{6}{10}^{\circ}$.

29. Can you give any account of the degree of softness acquired by the London pipe waters when boiled, as is usually practised for household use?—In the summer of 1841, I had the curiosity to make several trials of the hardness of boiled New River water; the following table presents the results:—

					Hardness.
1841.	May	.	.	Tavistock Hotel, Covent-garden	$7^{\circ}1$
,	July 31	.	.	The same	$6^{\circ}0$
,	Aug. 1	.	.	The same	$7^{\circ}4$
,	Aug. 2	.	.	The same	$5^{\circ}2$
,	Aug. 4	.	.	The same	$4^{\circ}8$
,	Aug. 16	.	.	Bedford Hotel, Covent-garden	$2^{\circ}9$
,	,	.	.	Hummum's Hotel, ditto	$6^{\circ}8$
,	,	.	.	Private family, ditto	$3^{\circ}0$
,	,	.	.	Private family, Charlotte-street, Bedford-square	$4^{\circ}0$

At University College a large boiler of water, being kept heated for

* A new Process for purifying the Waters supplied to the Metropolis by the existing Water Companies. 4th edition. London, by R. and J. E. Taylor, Red Lion-court, Fleet-street. 1849.

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two hours and a-half, showed $8\frac{2}{10}^{\circ}$ of hardness. [There is a very remarkable fact that I have observed on the comparative result of the process of prolonged boiling, and of the process of softening by means of lime-water. Both processes result in nearly the same degree of hardness, but the lime process gives a result much less alkaline than the boiling process, although the contrary might have been expected. Thus in trials of a specimen of the Thames water, I found that boiling and that lime-water each softened the Thames to about 4° ; but while the alkalinity of the boiled specimen was rather above 4° , the alkalinity of the specimen softened by lime-water was rather less than 2° ; and yet in this case the lime-water had added about 13° of alkalinity to the Thames.]

30. What other results from the application of your process can you give?—The Thames I found of hardness $14\frac{4}{10}^{\circ}$, of alkalinity $13\frac{6}{10}^{\circ}$; this, after purification, was of hardness $4\frac{2}{10}^{\circ}$, of alkalinity $1\frac{9}{10}^{\circ}$; the proportion of lime-water was 3 to 38. By long keeping this same water became $13\frac{7}{10}^{\circ}$ of hardness. The general result upon the waters of the Companies in London I found, by a great variety of other trials, to be this, that they acquire the same degree of softness by the process as when you mix the original water with distilled water, in the proportion of one measure of the original water to three measures of the distilled water; such is the general result as to London. I will mention another case in the neighbourhood of Watford, on the river Gade, where I found the hardness to be $18\frac{4}{10}^{\circ}$, and the alkalinity $17\frac{4}{10}^{\circ}$. By treating this water with one-tenth of its bulk of lime-water, the hardness was reduced to $2\frac{9}{10}^{\circ}$, and the alkalinity to $1\frac{4}{10}^{\circ}$; the softness of this purified water is the same as the softness of a mixture of one bulk of the original water with five bulks of pure distilled water; in other words, only one-sixth of the original hardening matter remains.

31. What would be the difference in the action of those waters, purified and unpurified, upon soap?—One hundred imperial gallons would require of the strongest white curd soap that I have ever used, the following quantities in order to form a lather:—

	Unpurified.	Purified.
East London	31 oz.	10 oz.
Thames	28 oz.	10 oz.
New River	26 oz.	9 oz.
Gade, near Watford . .	36 oz.	9 oz.
Mean	$30\frac{1}{4}$	$9\frac{1}{2}$

[I reckon 400 gallons of water per head, per year, to be a moderate allowance, for so much water as is made use of along with soap, chiefly of course in the washing of clothes.] If any member of the Commission be desirous of forming an opinion for himself, how much more agreeable it would be to wash with soft water, I would recommend that he order his wash-hand basin to be supplied at night with water that has been long boiled. This water will be cool enough to be used next morning; it will have been softened by the boiling—not more

softened than by my process, probably not so much. Then by putting into one basin the water that had been boiled, and putting into another the original water unboiled, he may form some idea of the softening that the process would produce on the whole water supplied to the metropolis.

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32. Do you know what relation the cost of soap consumed in London bears to the gross water-rent?—I reckon the cost of soap consumed in London to be about double the gross water-rent. The quantity of soap consumed in England, Wales, and Scotland, can easily be ascertained from official returns. From these the consumpt of every individual of the population appears to be nearly $7\frac{1}{2}$ lbs., or 120 ounces, which, at 1*d.* for three ounces, or 50*s.* per cwt., comes to an expense of 3*s.* 4*d.* for each person. There are no official returns from which to give the consumpt of soap in London alone; but after making diligent inquiries as to the consumpt of soap in families that washed on their own establishments, and obtaining what I believed was the best information that the trade could afford, I came to the conclusion that the average consumption of each person was about double in London what it was over all Britain—that is to say, 15 lbs., which comes to 6*s.* 8*d.* for each person. It is to be remembered that London is a hard-water district. The Commissioners must be aware that there are at present no very accurate data for an estimate of the water-rent paid by each person in London, but 3*s.* 4*d.* seems as accurate an estimate as can now be made. Thus 10*s.* for each person is the cost of soap and water in London; 6*s.* 8*d.* for soap, and 3*s.* 4*d.* for water. Since the soap costs twice the water, whatever be the rate of saving on soap, that rate will become twice as much when reckoned on the water. For example, if the saving by softening the water be only 5 per cent. on the soap, it would be 10 per cent. on the water.

33. What is the total soap used in London?—About 1,000 tons a-month, at about 50*l.* a-ton, and along with it is used about 250 tons of carbonate of soda, at about 10*l.* a-ton, costing together 630,000*l.* a-year.

34. Does the softening of water by your process affect the taste?—It takes a little of the saline character from the taste, in consequence of the removal of the chalk. It does not appear, so far as I have had an opportunity of observing, to render the taste objectionable. The opportunities I have had of observing were these. In Aberdeen, when my friends came about my laboratory, I let them taste the purified London waters, listening to their remarks without making any; and in London I caused as many friends as visited the laboratory where I was working, to taste the purified water, and I never found one object to the taste. In Professor Graham's laboratory in University College, where a quantity of New River water had been purified and left in a large glass, the Professor told me that he observed that his laboratory pupils went to that glass for water to drink through the day, in preference to the pipe-water.

35. Would the application of your process be attended with much expense?—Two years ago I made all the inquiries I could, and my impression then was that the expense of the materials would come to somewhere about 1 per cent. upon the gross water-rent of London.

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Probably the other expenses, of interest on outlay, and of conducting the process, would not much exceed another per cent. (See Q. 54, 57—61.)

36. You are probably aware that the water supplied by the water Companies is supplied from the river Thames; is there not a marked difference between the composition of the river water and that obtained from the wells occasionally in the metropolis?—Generally speaking the wells are harder, much harder. I may give a few instances. Torrington-square well, which was the hardest I examined, stood about 80° of hardness. The well at the gate of University College stood 32° . A well in a private house, Charlotte-street, Bedford-square, stood $43\frac{1}{2}^{\circ}$. Red Lion-square pump gave $61\cdot5$ of hardness. Among the London wells there is one exception, and a very notable and important one; that is, in the deep wells. I refer to the artesian wells; they are softer. I have examined the deep well of Apothecaries' Hall, the one at Combe's brewhouse, and the one at Truman and Co.'s brewhouse. They gave each almost exactly the same degree of hardness, namely, $51\frac{5}{10}$.

37. Do you happen to know the depths of those wells?—I cannot state that particularly, but they are among the deepest wells in town. There is a very remarkable peculiarity belonging to the water of those wells, which is, that they are very highly alkaline. [The degree of their alkalinity exceeds the degree of their hardness by 17° , according to an analysis recently performed at the Royal College of Chemistry, on account of the presence of a large proportion of alkaline bicarbonates.] In respect of the excess of alkalinity over the hardness, they are different from almost any other water I have examined, save that from the artesian well in Paris. The consequence of the large proportion of alkaline bicarbonates they contain is, that if you boil any of these waters you will find it become nearly as soft as water can be. Very perfectly the earthy salt is precipitated; but while you are free from earthy salts you have got so much of alkaline salts that you can very distinctly taste the alkali in the water; so that the water from any of the very deep wells in London is, in fact, when boiled, a weak solution of carbonate of soda or carbonate of potash

38. Sufficient to produce any effect?—I think small doses of alkaline salts always act medicinally on the kidneys, and I think that portion of the water is the only portion of which we can say with confidence that it does produce medicinal effect. It was on that consideration that I alluded to the alkaline bicarbonates as a most important ingredient in the water.

39. Is there any appreciable quantity of vegetable matter in the water which is in use in the metropolis?—Uniformly there is a considerable portion of vegetable matter in the water supplied to London by the companies.

40. Has the offensive smell of certain water any connexion with the presence of organic matter?—Certainly. When the water put into a glass vessel acquires an offensive smell, that can be attributed only to the presence of vegetable matter, or other organic matter undergoing a change.

41. Is the animal matter which passes into the river by the sewers

separable by filtration or any other means?—The solid portion of it may be separated by filtration; but not the portion of it held in solution. At the same time I must say that I think very undue weight has been given to the presence of organic matter, and especially of animal matter; as if, because it was inseparable by filtration, it still must retain the same offensive character as when it entered the water. I think this will appear exceedingly unlikely, when you observe what occurs in the well-known process of making nitre artificially, where such animal matter as the washings of the cow-house is converted so readily into the basis of nitric acid; when you consider how readily such matters are likewise changed in the usual process of vegetation, and when you consider, further, how readily dead animal matter changes spontaneously. For such reasons, I think that it is assuming far too much to say that such animal matter as passes into the river remains there unchanged, especially remembering how freely a river is exposed to the action of the air, and recollecting the other matters that are present, so calculated in such circumstances to increase chemical action, as, for instance, the alkaline substances present. Under such circumstances, I think it is very unlikely indeed that the elements of animal matter do not undergo change, and rapidly too, into some other state of combination.

42. Is the presence of water insects of any consequence, and is that peculiar to London water, or have you found them in the water of other districts in England?—Those insects are not peculiar to the London waters; but the London are the first of the waters supplied for the use of the inhabitants of towns in which I ever saw them. They are not general in the waters of other towns, at least in Scotland, and are nowhere to be found except in such waters as are not in a choice state for drinking. They are an indication in general of a vegetating process going on in the water; I think I have observed, from examining a great variety of specimens of water kept in glass vessels, that the two things generally go together, the vegetating process and the breeding of those insects. Either circumstance I should apprehend to be a presumption of the other, and to indicate a state of water unfit for drinking.

43. Can you state what effect on health is likely to ensue from the constant use of water containing animal or vegetable impurities?—I am not prepared to make any statement upon that subject; nor am I aware that, in regard to a question of so much interest, there has been much accurate information obtained. However, there is one very obvious consideration as regards the health of the inhabitants, that if you have water not fit for drinking, in which there is matter offensive in any degree, by so much as the water is offensive you lessen the habit of drinking water. Now, you cannot restrict the supply of water to such quality as is naturally repulsive; you cannot thus render the inhabitants abstinent from water, without interfering with the healthful functions of their bodies. It was with no small concern that I learned how few of the inhabitants of London, and especially of the lower orders, drink water. In making my experiments upon these waters, when I inquired of the servants about me how they liked particular waters, it was with perfect surprise I discovered that they—generally mere lads—knew nothing about the taste of the water. They are the

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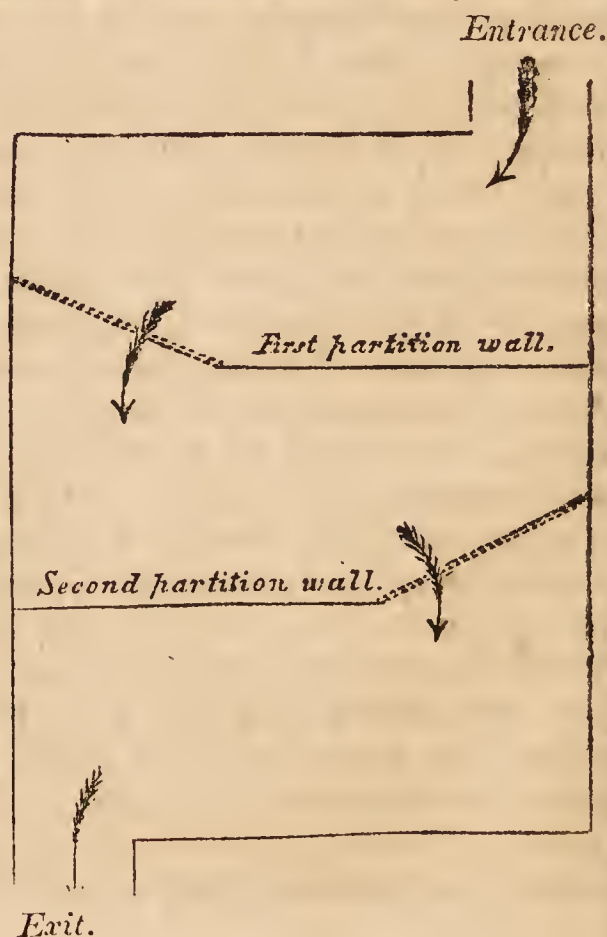
same sort of persons as would be accustomed to drink water in other places, but they have other beverages here. I should, perhaps, not speak as to the general habit of the inhabitants, but only of what little I have observed in such circumstances.

44. What do you mean by mechanical impurities?—Such impurities as you can see in water; solid matter loosely diffused through it.

45. What are the ordinary means in use for the removal of those mechanical impurities in water?—All the usual means may be reduced to two, the process of subsidence and the process of filtration.

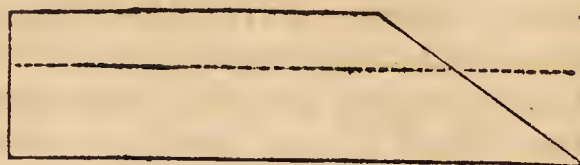
46. Have you any suggestions to make with regard to reservoirs of subsidence?—In constructing reservoirs for water to supply a large town, there are a great many important provisions to be made. I think there is one point that must be laid down almost as a general principle, namely, that you should never unite the supplying of water to a town with the supplying of water to a canal, or to mills, or to any other mechanical object; and the reason is, that whenever you apply water to a mechanical purpose there is no end to the demand for it. Coloured or colourless, pure or impure, it will answer equally well for mechanical purposes; and the persons interested in mechanical applications of water will be quite willing to let water be taken in such as is not at all fit for drinking, for washing, or for chemical manufactories. With regard to the size of reservoirs, there are reasons why they should not be too large, and there are reasons why they should not be too small. Reservoirs should not be so large as to encourage vegetation in them. I think I have observed some reservoirs where there is this defect; they have been so large that the water remains long enough to be comparatively corrupted. This is a very grave defect; and in order in part to remedy it, the use of some substance repulsive to vegetation, in order to line the reservoir, might be expedient; for instance, asphaltum. Again, reservoirs, on the other hand, may be too small. They should always be so large as to hold a stock of water for as many days as may be necessary to avoid taking in a supply at a period when the water is not in a fit state for use, from rain or other causes. For this reason it is in general expedient that the first reservoir into which water is pumped from a river should not be far from the river, nor high above it, so that any given amount of machinery may be able to fill it the more speedily: so much with regard to the size. Then the reservoir should be used as a means of subsidence, and helps to subsidence ought to be adopted. Among other helps, I think it is expedient to have partition walls in the reservoirs. Here is a sketch I drew in the other room.—[The

Witness here produced the same.]



Suppose the water enters at the utmost arrow, it passes round the partition walls, in the direction of the arrows, as shown in the drawing. If you observe a reservoir without partitions you will see this take

Section of the second partition wall.



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Water level.

place. When the wind gets up so as to sweep the reservoir, say in its length, then, the sides of the reservoir being a little above the surface of the water, the waves would not begin to be formed for some considerable distance from the wall; and, in proportion to the length, they would go on increasing in size. The partitions would have the effect of preventing the agitation in a considerable degree. These walls would have another effect; they would give a regular flow of water from the point of entrance of the water to the point of its exit; whereas without those walls it may happen, and I have observed such a thing to happen, that you may have water of one description in one part of your reservoir, and water of a different description in another part, where there is a defective flow of the water. But in a reservoir with walls, the water that has first entered the reservoir comes out first. [Such walls might also, perhaps, afford support to roofing, or other means of covering in the reservoir, and protecting the water from the action of the sun, which is a great promoter of vegetation.] Floating diagonally at the place where the water passes beyond each partition wall, there should be a floating spar, with wooden pegs in it. This is represented in the sketch of plan by dotted lines. The use of it is to stop straw, and similar floating matter, as well as to break the waves at that place. Further, with regard to the reservoir, there is a very important point that I think has not been attended to in water-works for towns, though I have observed manufacturers attend to it; that where water is to be obtained from different sources, and where, in consequence, it is of different qualities, I think it is quite necessary that, before the water comes into the reservoir, all the different kinds should be thoroughly mixed. This is the practice in the district of England where, I think, the treatment of water is best understood of any part of the United Kingdom, that is Lancashire. The practice in manufactories around Manchester almost uniformly is, where you have two different qualities of water, to mix them into one stream, and let them run together in a narrow channel pretty swiftly, and for some distance, before they come into the subsiding reservoir. One advantage arises from this: it often happens that the saline impurities of one water act upon those of another. Such an action, wherever the waters are of a kind to occasion it, is immediately produced under the arrangement described. The different waters are mixed together before they enter the reservoir, and are ready for the precipitation consequent on their mixture immediately taking place, whereas if they entered a reservoir separately, the water from one source might run into one corner, and that from the other source into another; the one might be muddy and the other clear; they might never be properly mixed; and wherever they came in contact, there would be a muddiness slowly formed. Whenever you have any dirty water, the subsidence of the dirty matter is greatly aided by mixture, and a consequent pre-

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precipitation. The mixture of different waters causes them to act on each other; occasions a readiness to precipitate, and the deposit of floating mechanical matter takes place in this manner much more readily, in consequence of the thorough admixture of the two kinds of water. The success of the filtration of water on the large scale, I think, is greater in Lancashire than in any other part of the United Kingdom. I attribute a very great portion of that success to this arrangement, for it is a point universally known to chemists, that you cannot filter water clearly unless it be in such a state that it will spontaneously deposit the solid matter by subsidence, and leave the water clear. If subsidence leaves the water still milky or unclear, the water almost universally passes through the filter milky. I would add, in regard to subsiding reservoirs, that I think water should be taken not from the bottom but from the top of the reservoir. I am sorry to observe it is almost an universal rule to take it from the bottom: the engineer finds it more easy to take it from thence.

47. By what means would you draw it off from the top?—By any known device of engineering that is expedient under the circumstances. I would take it not far from the surface. In one case of a manufactory, I recommended that there should be a large float on the top, attaching to it the open end of an exit-pipe, so that the distance from the surface of the opening for the exit of the water was always the same, the pipe having a moveable joint.

48. Will you state your opinion with regard to the different modes of filtration used on a large scale?—There are two modes of filtration that have been effectually used on the large scale, one called the Natural Filter, the other called the Lancashire Filter. I think that the natural filter was applied on a very considerable scale first, as far as I am aware, at Glasgow. On the River Clyde, a few miles above Glasgow, there is a very extensive convex, round bank of sand; buried in this bank, nearly parallel to the edge of the river, as well as to the surface of the water, and under its level, was a tunnel so constructed as to be without mortar above, but with mortar below. The water was allowed to filter into this tunnel, and to trickle from that into wells, and from thence it was pumped up for use. This method of filtration, in consequence of the success that attended the first great application of it at Glasgow, was imitated elsewhere on the banks of the same river, and in other places, but most commonly it failed. One cause which led frequently to its failure was this, that springs were found in the ground, which afforded water perhaps harder than that which was filtering. In the case of the other trials of the Clyde water, the natural filter afforded springs containing iron, and injurious for the purposes for which the water was designed, especially washing and dyeing. Such a defect must occur, more or less, wherever you have a natural spring in the ground of worse quality than the water you intend to filter. When you use the natural filter, you must advert to the liability, greater or less, of the filtration being interfered with by springs. But there is another defect, which has led me to the conclusion, that, upon the whole, natural filtration is not an expedient method for towns. The defect I refer to rests upon this consideration: the level of your filter is fixed; the level of the water in the river will

vary. In exceedingly hot weather this level is lowest; but it is in exceedingly hot weather that you require the greatest supply of water. At the time therefore when you have the greatest demand for water, you have the smallest supply; and I believe it will be found on experience, that wherever such a filter has been adopted for the supply of a town, the parties managing the water-works are compelled, about Midsummer, to take water directly from the river to supply the deficiency to the town. Now this defect is one so constant, and that so essentially belongs to the method, that I think we ought to be very cautious of adopting that as the mode of filtration in any case. I would say also, that there is probably another objection to that description of filter that you have not it under command; it may clog up by use, and if it do, you cannot clean it; at least I do not see the means of doing so. The natural filter, therefore, I do not consider eligible for use.

49. Do you know the Lancashire method?—The Lancashire method may be easily described in general terms. Supposing you have a flat horizontal surface to form the bottom of the filter; that is puddled. Above this you spread gravel, and, in general, very large stones. In the spaces between those stones you have the water received and passing out by means of little tunnels near the bottom. These are formed in a variety of ways. A very good method of forming them has been recently practised, and answers very well; the using simply of agricultural draining tiles. Those little tunnels are for letting off the filtered water all around them. If you have large stones, the interstices between those large stones constitute a receptacle for holding the filtered water. Above the large stones you have large gravel, then smaller gravel, till you come to sand. The whole of the cleansing part of the filter consists of sand. This is of a larger grain than the common sea sand, except such as we see in rocky districts at the mouths of rivers on the shore; large-grained sand of a uniform size. The filter, I think, may be worked so low as four inches of the sand; I think it is constructed at about 14 inches. From 4 inches to 14 inches is a workable depth of sand. A very small depth of water above the surface of the filter is employed; in fact, in using this filter I think it is usual to see some part of the surface of the filter uncovered; the whole action is found to be concentrated at the surface. The solid matter intercepted does not penetrate perhaps so much as a quarter of an inch, so that by removing a very small film from the surface you get a clear filter; this removal is performed by a workman from time to time. I think that this process of filtration is efficacious in removing mechanical impurities to an extent that could scarcely be believed without seeing the process. What dirty water is thus filtered and used in some of the first manufactories of calico-printers, where one would think good water was at least very desirable, would not have been believed by me to be possible, if observation had not made me familiar with the fact. Clearing the filter is a matter of very small expense in a large manufactory; neither is the structure of the filter expensive. What is scraped off the top is set aside, and at the end of such a period as a year, is washed and put back again on the surface of the filter, so that no renewal of fresh sand is necessary. Such is an outline of the Lancashire filtering. There are occasionally seen in some such filters, iron

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pipes rising upright throughout the surface of the sand. These pipes are open, and communicate with the little tunnels. The use of them is simply to let the air escape, so that the pressure of the air that might be confined in the tunnels under the sand does not prevent the action of the filter. Of all the methods of filtration, I consider the Lancashire the best. It is particularly to be recommended for its cheap construction; and the facility of cleaning the filter is an important advantage.

50. Is it applicable to large bodies of water, such as are required for cities?—Yes; I have seen it applied to great paper works, which require very large supplies of water. There is no limit to the application of it.

51. Is it applicable where there is a great flow of water going into reservoirs?—I know no circumstance to hinder the application of it on any scale whatever.

52. Where there is a very rapid consumption of water; where the flow into the reservoir, and the demand for the water of the reservoir, is very rapid?—It would require in that case a larger filter. The process is so easy in its operation, and so rapid in its effect, that I am not aware that any amount of water might not be filtered by it. In Glasgow all the water is professed to be filtered for the use of a population of above 300,000. Now I have no hesitation in saying there would be less difficulty in filtering by the Lancashire process than by the methods that have been adopted there. (See Q. 64, 65.)

53. The effect of your statement is, that the different waters supplied by the London water companies, varying in hardness from 16 to 11, and so on, would be reduced by the improved process three-fourths in their hardness?—Precisely so.

54. What would be the cost of the process on any given quantity of water?—That is a calculation that cannot, from the nature of it, be made until a specific case shall arise. You can easily ascertain the quantity and the cost of the lime that is requisite, when you know the quantity and quality of water that is to be purified; and the cost of that material, according to the best information I could obtain when I made inquiry two years ago, could not be more than 10*l.* a-day, in order to purify all the water supplied to London.

55. Might it not be proper, as a means of saving expense, to purify only a part of the water, say a half, and leave the rest unpurified, for watering streets, and the like purposes?—My impression is, that the difference of expense between purifying the half and purifying the whole, consisting mainly, as it must, in the cost of the material, is so little, that it ought never to be made a question whether the whole should be purified or only a part. A halfpenny a-year would supply burnt lime to purify water for each person in the metropolis. Besides, the larger the scale, the process is the easier, and the more advantageous in its application.

56. Do you regard it as of any consequence what quality of water is used for such a purpose as watering the streets?—Not certainly as a matter of indifference. The best waters now used for watering the streets of London are probably the hard springs. They are free from vegetating matter. The pipe waters are not so; and waters with this kind of taint communicate it to other water, or other organic matter

that may come in contact with them. When it is considered how readily effluvia will rise from a heated street covered with a film of water, it ought not, I think, to be regarded as a matter of indifference whether untainted water should be used for streets. Supposing the pipe waters of London were purified by my process, they would certainly be more wholesome water for the streets; and even if to every cart of such water were added a gallon or two of lime water, a liquor very inimical to vegetation, probably it would be more wholesome still, free from any character that belongs to heated marsh water, unfavourable to vegetation, but favourable to animal matter assuming the form of nitrates. In some towns I have seen the kennels dammed up, and the water sprinkled thence by a shovel, or some such instrument. Thus, no doubt, the dust is laid; but the effluvia is a more unwholesome evil than the dust. Water tainted and smelling, as I have occasionally observed water in London, is worse for watering streets than even kennel water.

57. For the whole supply of London, the expense of the burnt lime would be 3,650*l.* a-year, according to your calculation. What other expenses would be incident to carrying it into effect?—The other expenses would depend entirely upon what conveniences the water companies have just now. The West Middlesex Company, for instance, have extensive reservoirs, not more extensive than under suitable arrangements would be necessary for the proper treatment of the water. There the expense might be very little, for they are in possession of reservoirs. If the purifying process was to be applied by a company that possesses no reservoirs, or inadequate reservoirs, then there would come in the expense of the additional reservoirs; but, independent of the providing of the reservoirs to such an extent as is at present necessary for effecting subsidence properly, the expense of the process and of the erections for working it, would be very small.

58. What would be the additional expense to that company which had a reservoir?—That is a question I am not prepared to answer, from the circumstance that having invited the attention of the various water companies to this process, I found that with one exception, and hardly a second, they civilly declined so much as to look at the process. The principal exception occurred in the case of the Grand Junction Water Company, of which both the secretary and the engineer inspected the operation of the process on a small scale, and also satisfied themselves of the remarkable changes of quality induced by the process: at first the secretary, and after a long interval, one or two directors of the West Middlesex did also satisfy themselves upon the same points, but it was merely looking at the process, nothing more.

59. Though not prepared to make the calculation, can you give any approximation to the other expenses?—I cannot profess to offer any advised approximation, for the point is one on which an engineer must be the judge. I was prepared to point out to the engineer of any of the water companies all that was necessary to be attended to for doing justice to the process, expecting he would state to his own company what the expense would be in the instance of that particular company; and, if for my own satisfaction, I were to make an estimate applicable to the case of any water company in London, it could only be by

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employing an engineer. That, however, would be so speculative a procedure, that I have not thought it called for on my part. I was indeed very anxious to furnish the engineers of the water companies with every information in my power, so as to enable each company to form an estimate of the expense by its own engineer, and not from any opinion of mine, nor of any engineer employed by me; but the engineer of only one of the companies availed himself of the invitation to witness the process; and whether he ever formed an estimate for the information of the company, I never heard. [As far as I have since been able to gather from intercourse with engineers, it is likely that the apparatus necessary for working out my process on the large scale, will be pretty much the same in expense as apparatus for working out the process of filtration on a like scale. After the application of my process no filtration is necessary.]

60. You have been asked with regard to the expense; have you any hesitation yourself in stating, though you do not give a precise answer as to the amount, that your processes are not in themselves essentially expensive?—Certainly, such is my impression.

61. They will consist essentially in effecting the solution of lime in the first instance; secondly, in the proper commixture of that solution with the water to be purified; and thirdly, in affording facility of deposition?—Precisely so. Indeed, I find it impossible to think of my process as involving the consumers in additional expense; for, supposing my anticipations to be so far erroneous that, instead of costing 1*d.* per head of population, the purification, and consequent softening of the water, should cost so much as 4*d.* a head, still this 4*d.* of outlay on the water-rent would be compensated to the consumer by a saving of only three-quarters of a pound, that is, one-twentieth of the soap required for the consumption of each person; and the saving, arising from the softness of water, in the wear and tear of linen, in the quantity required of such an article as tea, and in the wear and tear of boilers of all kinds, has to be added to the saving in soap.

62. When you refer to the condition of the water in London, and particularly to that quality of hardness, are you to be understood that your process consists in applying the amount of lime which is necessary for the deposition of the super-carbonate, and not beyond that?—No more, and no less; but especially no more.

63. When you refer to the quality of water, and speak of the hardness of water in different districts of the country, have you also noticed the amount of organic matter in water from wells in London, or do you wish that those observations should be considered as applying principally, if not entirely, to the water supplied by the companies?—My observations were mainly directed to the waters supplied by the companies, because they were the waters I was best acquainted with. With regard to well waters in London, except a few here and there, I have been very little acquainted with them. Anybody may observe that water when kept in a bed-room, or a sitting-room, if it be the New River water, or the Thames water, has a tendency, if kept a few days, to vegetate, and cover the bottom of the water-bottles with vegetation. Now, I have not observed in the particular spring waters that I have been accustomed to drink in London any such tendency. Whether

this freedom from vegetation is universal in the spring water of London, I am not prepared to say. Professor
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64. In referring to the filtration of water, you mentioned that it is only the mechanical impurities that are removed by filtration?—I did so.

65. Do you mean that to apply to a filter of sand or to filters generally?—To artificial filters, such as are generally used. I would like to make a statement in reference to the habits of water in regard to a point that I think is not generally known, but that came once under my observation very strongly. I believe that filtration, through a great depth of filtering material, such as occurs in the operations of nature, does take away colour. I believe that, from what I have observed, particularly in the case of water filtering from a pond on the top of a small hill so as to escape as a large spring near the bottom; but what the nature of the discolouring process is it might not be easy to state, and perhaps not easy to conjecture. But the quality alluded to as belonging to water must be kept in view in attempting to explain this discolouration, and to explain changes that take place in the water of rivers and lakes, else there will be unfounded prejudices entertained; it is the tendency water has to purify itself spontaneously by natural processes. We never do see a very large body of water collected together, except in a pretty clear state; there is a natural process, a vegetating one, that goes on very readily, freeing the water from vegetable matter and all that sort of matter that makes water what we call dirty. If you look to a stream coming from a dye-work, you may discover in it, at a very little distance from the dye-work, a vegetation that takes place; if it be, for instance, from a madder-work, you will find a reddish vegetation. The vegetation I refer to is very easily distinguished by its assuming a form that reminds you of a sooty brush. When you lift it out of the water it is slimy. You can see it in its natural form only in the water. Even in the common kennels in the streets, if they be kept constantly running, and be not frequently supplied with fresh water, you will find such vegetable matter; this results from a spontaneous vegetation. In its progress, a purification of the water takes place universally. A remarkable occurrence took place in an action at law, where it was alleged that a certain water was destroyed for certain purposes by a dye-work. Specimens had been taken for more than a year. Those were bottled up, and sealed and labelled, and the individuals that collected the specimens were prepared to swear those were collected fairly, and in the state in which they were preserved. I had an opportunity of examining all those specimens, and although they were marked “brown water,” “red water,” and so forth, I found all of those waters had spontaneously cleared. The impure colouring matter had subsided, not as small dust, but in flakes that could be shaken up, and that floated in clots. Such is the process which I apprehend may account for how very readily impure water left for some time comes to be spontaneously purified. Probably it is such a process as that which occurs in a natural filter, where the water passes a certain distance; and probably it is that which takes away the colouring matter; but that I do not know. I might perhaps also mention, that any process which throws

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solid matter down from solution, sends down also diffused dirty matter ; for instance, any gentleman in London, who has boiled water brought to him to shave with, may occasionally see a powder settled at the bottom: this is chalk; but it is not white, for all the colouring has gone down with it. So likewise, in my process of precipitating chalk by lime-water, what falls is not white ; it is coloured differently from pure chalk. The purified water, too, is less coloured than the original water, because the colouring matter has fallen down with the chalk.

66. Though it may have been previously in solution?—Yes.

67. In reference to the process by which you purify water, it essentially depends upon the deposition of the carbonate of lime. Have you had any opportunity of forming an opinion as to the time that may be required for such deposition in works on a large scale, and also in respect of the probable influence of such deposition upon the materials used for filtration, and whether you can effect that deposition so as to be secured against any tendency to increase the crust that might appear in the pipes in some cases?—With regard to the time necessary, I have employed, as the best means of observation, large glass vessels, because there I could best see what takes place. Ultimately I came to use vessels of the size of seven gallons. It was in such vessels I practised the process here, when I invited the inspection of the water companies. When this process is applied, there is this peculiarity, that the more the process has to do, the quicker it does it, and the more decisively. For instance, a water of 16° of hardness will deposit faster than one of 12° ; a water of 12° of hardness will deposit faster than one of 8° ; and water of 12° , according to my observation, may be reasonably expected to clear in 24 hours. Indeed, my impression is, that such water generally clears in 16 hours after mixture with lime-water. With regard to a water of 10° , I should expect, though I have no experience, that the deposition would be still less rapid. As you get below the hardness of 8° , I should expect the process would be so slow that it would become a question whether the application of the process was expedient ; and the only rule I was able to give in the specification was, that every particular water should be treated, in a suitable proportion, with lime-water, and the time of its precipitation observed, so as to afford an opportunity of witnessing the habit of the water when under the operation of this process, before coming to the resolution of adopting it. The precipitation of the chalk formed, along with the mechanical impurities, is so very effectual under this process, that no filtration would be needed. With regard to the pipes, if a reasonable time were permitted for deposition in reservoirs, certainly I should not be prepared to expect any incrustation in the pipes. With regard to incrustation, I may also state, that the water which has undergone this process affords no visible deposit on boiling, although the unpurified water does so extensively.

68. Are you aware whether the insects you refer to are destroyed by lime in the quantity employed in your process?—Undoubtedly lime does destroy the insects ; so much was it my impression that they were all destroyed, that I stated so broadly in my pamphlet ; but I afterwards occasionally observed one or two to escape in some experi-

ments, and I suppose, also, that some of the insects are of a more hardy kind than others, and so escape. My impression for a long time was that every one of these creatures was destroyed.

69. Have you ever, in examining the matter precipitated during the process, found reason to believe, from actual experiment, that there is organic matter thrown down along with the material so deposited?—The evidence for believing that the process removes colouring vegetable matter consists in the appearance that we get. For instance, if the water be brownish, we get the chalk brownish; whereas, if we use the very same lime-water, and precipitate chalk from it by any fitting agent dissolved in distilled water, we get it pure white; besides this, the water floating above the coloured chalk precipitated in purifying a London water is freer from a portion of colouring and organic matter than the original water compared with it side by side, for such matter has gone to the bottom in the chalk. But I have also dissolved the precipitate formed in the purifying process by means of very dilute muriatic acid, and have in this manner seen left the remains of insects that had been killed by the process and buried in the precipitate.

70. What qualities injurious to any special use are imparted to water by the different geological characters of the countries from whence it arises, or over which it flows?—The connexion between the qualities of a water and the character of its geological source, is a question of very great interest, and which I much hope may be answered very soon. I believe that it will be found, that out of every specific kind of rock will come either exactly the same quality of spring-water, or within a very small range the same; so that you will be able to predicate from the rock what kind of water you will get; and I think it will be possible very soon to predicate from the water what kind of rock it comes from, and in a given district, to know the part of the country from which any specimen of water may have been taken. Last winter I was on the eve of commencing a series of experiments on that very point, selecting for examination only spring-waters coming directly from known rocks, when illness interfered and put a stop to my researches. The question is, however, of the highest importance practically. The facilities for making researches on the qualities of waters, so far as connected with the geological character of the district, are great, by means of the new processes I alluded to for examining water. By those processes, an ordinary water may now be examined with great accuracy and great facility. You can, in the course of a day, examine as many waters as would have taken weeks before. Although not at present prepared to answer this question particularly, I am entitled to say in general that there is a very close connexion between the qualities of water and the geological character of its locality; and ever since it has become possible to examine the useful qualities of water so easily, I have had an anxious desire to see the examination of waters embraced as part of the operations of the national geological survey.

71. Will you state the different effect produced on water by the conveyance of it through lead or through iron pipes?—Through iron pipes, I think, there is no apprehension of risk to be entertained, except simply from the corrosion of the pipes, and the ill colour that would be

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imparted to linen washed with it. With respect to lead pipes, I would say that the less lead is used the better in all cases; because, independent of carbonic acid, lead is very susceptible of being oxidized on the surface, and carried off rapidly, so that the powder of oxidated lead is apt to be conveyed into pipes along with the water. In general, the less lead is used the better; but it may be used for conveying water from the main iron pipes in the streets to the houses, provided the water be on the system of constant supply. The precaution, however, will be necessary to let the water run for five or ten minutes if the pipes have been for any considerable time out of use.

72. What is likely to be the effect of the oxidation of metal pipes on the health of the population where the mode of supply is one by which the pipes are alternately full and empty?—There is risk of a greater action on the pipes when they are alternately full and empty, than when constantly full, in consequence of the greater exposure to the action of air, which is essential almost to chemical action on the pipes. Perhaps I may be allowed to add, with reference to the action of water upon lead, that I tried very carefully, in University College here, the action of the New River water in its natural state, and of the same when purified by my process, against distilled water; and I found that while the distilled water acted very readily, that purified by my process did not act perceptibly; neither did the unpurified water. (See Q. 18.)

73. Have you at any time found the organic impurities of London water in so large a quantity as to be evident to the senses of smell or taste?—I have; one instance occurs in the note-book before me, “10 September, 1841; West Middlesex water, obtained from Percy-street, Tottenham Court-road, smelled like bilge-water;” I remember inquiring, and I believe that the offensive smell is apt to be much aggravated by the state of the intermediate cisterns that are attached to the houses.

74. In those cases where it is not so evident, you were understood to say that you considered the presence of animalcules as a sign of the water likewise containing small quantities of animal or vegetable matter in a state of change?—I cannot speak at all as a naturalist; I might speak perhaps erroneously; but I meant merely to make this observation: I have seen the two so constantly accompanying each other, the water insects and vegetating matter, that I have accounted them companion circumstances.

75. Are the animalcules of which you speak those visible to the naked eye, or those which you discovered by a microscope?—I speak only of such as I have observed by the naked eye; but it is wonderful how the naked eye improves in its power of observation by some practice in watching those animalcules. In a globular glass vessel of crystal, or in a basin of pure white, they are very easily discerned.

76. Have you found any water supplied to the metropolis more especially characterised by those animalcules than other?—I found the animalcules to abound in the waters of all the companies. I have lately examined a specimen of water from a cistern in the house of a friend in London, who was of opinion that the water was of late somewhat harder than usual, and it was only to try the hardness that I obtained the specimen. The hardness proved to be 14° , which is

harder than the pipe water commonly is. But before trying the hardness, I had the curiosity to count as many monocoli as I could distinguish in sun light by the naked eye. For this purpose I divided the specimen, which consisted of a quarter of a pint, into three parts. The monocoli are easily distinguishable by their darting motions. I found in the quarter of a pint 14 or 15, I was not sure which. This comes to between 56 and 60 a pint, and 450 and 480 a gallon. But the real number of creatures visible to the naked eye was of course more than this. As to the smaller creatures, visible only by the microscope, I made no observations. The servant had no instruction in taking the specimen, but only to rinse the bottle well with the water before filling the bottle, and that he was to take the water from the pipe, and not the filtered water that was used in the house. The specimen did not strike an eye accustomed to the London waters as at all unusual.

77. Do you account this common?—I have never found them in the Scotch waters that I had been accustomed to in towns, nor indeed had I ever observed them at all in any town's water, till I examined London water.

78. Do you think the poor inhabitants of London are prevented from drinking the water supplied to them from finding objectionable matter in it?—Certainly.

79. Your experience being, that these classes of impurities are, if not quite exclusively, very peculiarly characteristic of the water supplied to London, should you not be of opinion that they might be accounted for by the quantity of decaying animal and vegetable substances carried into the Thames by the sewers?—Not so; for I find these creatures to abound in the New River and in the waters of the West Middlesex and Grand Junction Companies, although these are taken from the river much above any part affected by the sewage of London.

80. Whatever would diminish the quantity of decaying organic matter carried into the water, would be likely to diminish the quantity of these animalcules which are to be found?—Certainly; and such a diminution, it appeared to me, would be one of the effects produced by my process.

81. Are you to be understood that you have been in communication with some of the water companies in London respecting the introduction of your plan?—With all the water companies without exception.

82. Did you submit to them any specific arrangement by which it was to be carried out?—No; that was not the nature of my communication. I sent a circular to them, enclosing some copies of my pamphlet, explanatory of the process, stating to each company that I should be exceedingly happy to afford to gentlemen connected with it an opportunity of witnessing the new process, and of each satisfying himself as to the changes thereby produced in the water supplied by the company, and mentioning that I would so arrange that an hour might suffice to enable any gentleman to appreciate the improvements in the water resulting from the invention. No notice whatever was taken of my communication by two companies; another was too much engaged with other operations to take my process into consideration; but they said they felt great interest in it, and they were so good as to recommend me to try whether brewers, dyers, and other large consumers in

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their district would give it a trial. A fourth company thanked me for my "polite attention," and promised to read my pamphlet. I waited a month in expectation of learning the result of the promised perusal, but not hearing from them, I again wrote to the secretary, and received from him the following answer:—"At a meeting of our Board of Directors to-day I read your letter, dated 5th instant, to the gentlemen present." This was the whole of their answer. I heard from them no more. Then there was another company who promptly informed me, that having reached perfection, the sending my pamphlet to them was quite needless. As to the West Middlesex Company the secretary was very polite to me, and immediately came to look at my experiments, and expressed himself quite satisfied with the accuracy of the statements in my pamphlet. The directors for a long time declined to be witnesses of my operations, because they conceived that their water had been "bright, pure, and salubrious" for two years. After some weeks, however, one or two of the directors did venture to look at my operations, but thereafter I heard from them no more. The Grand Junction Water Company, by their secretary and engineer, inspected the process with a consideration that was very gratifying to me; but neither from them have I heard anything for near two years. The New River Company, without having sent anybody to see the process, gave an opinion that the process could not be worked on a large scale, or would be much more easily and economically applied by consumers on the small scale, more especially as the proposed purification would not be required, except for a very small portion of the water.

83. Have you not heard from some engineers of a water-work that there would be some mechanical difficulty in carrying out your plan on a large scale?—I have heard no such objection from any engineer of a water-work. Among such engineers connected with London, I have had business intercourse only with one gentleman, the engineer of the Grand Junction Water Company. He examined the process on the small scale, and conversed with me on the subject, with all the intelligence that might be expected from a well-informed man in his profession, but I do not remember any such difficulty being suggested by him. With one other engineer, that of the Chelsea Company, I had an accidental meeting in the country last summer, and had an opportunity of conversing with him on the subject; and I remember one remark he made was, that when orders were given by the directors for the application of such a process, he had no doubt that the means would be found.

84. Was there no objection made to the quality of the purified water?—One objection was made, on the suggestion, I understood, of a medical author of some name. It was that the depriving the water we drink of its chalk, might prove injurious to the bones of the inhabitants. The idea was founded on this consideration, there is lime in chalk and there is lime in bones: if you deprive the water we drink of one thing that contains lime, you must also deprive our bones of another thing that contains lime.

85. Had you no reply to offer to that objection?—Although much concerned to discover that the state of medical science in London could permit such a suggestion being made, and although much amused at the earnest conviction with which the objection was repeated, yet I cer-

tainly did not think a scientific answer called for; but I did suggest that the purifying process might still leave as much lime as was required for the bones, since in the town of my residence, there had been long water in general use containing much less lime than the purified water would contain, and yet the inhabitants were among the largest boned of the Queen's subjects.

86. Has any plan occurred to you on a large scale for the purpose of mixing lime-water in an extensive reservoir?—Certainly.

87. Will you explain it?—The method I think the most obvious would be, first, to determine, by the rules given in my specification, the proportion of lime-water necessary. Suppose the proportion to be 1 of lime-water to 14 of unpurified water. I take for granted there are a great variety of means, and of known rules, whereby an engineer can apportion and mix lime-water and unpurified water in the proportion of 1 measure to 14 measures. It would be presumption for me to suggest to any engineer the best method to select; but one obvious expedient that would occur to me would be, supposing by any process you could have one pipe issuing with lime-water and one or more pipes issuing with water to be purified 14 times as much, so as to mix the waters together; let the mixture run to and fro in a swift stream in a narrow channel in the usual method of mixing water in Lancashire; let the stream at last come into a reservoir. After such a plan as this, water should be introduced, after mixture, into reservoirs, and therein left to clear by subsidence; and my idea of the proper working of the purifying process on a large scale would be, that there should be a constant issuing in of the mixture at the one end of a large reservoir, and a constant flowing out of the clear purified water at the other.

88. You are aware that there have been Committees of the House of Commons on the subject of the supply of water to the metropolis?—I have read all the Reports.

89. You have seen, then, the mode in which it was proposed by the late Mr. Telford to furnish an increased supply of water?—Yes.

90. He proposed to take it from Hertfordshire on one side, and Surrey on the other; what opinion have you formed as to the modes suggested?—My real impression, from a consideration of the whole subject of water in connexion with London, is that the source of supply that should not be departed from is the Thames, it is so very copious. Then, with regard to the supply of water to London from a distance, there are many points that one would like to know beforehand; for instance, I found some water in the neighbourhood of Watford, in one of the rivers, the Gade, about one-half harder than the water here. One would require to know a little more about the hardness of all the waters that have been proposed to be brought to London, and to know whether there would not be a tendency to vegetation in conveying it from the source to London, at least if the water is to be conveyed in open channels. I do not mean absolutely to say there would be as much vegetation as we now have in the London waters; but I should like to see, from the experience of other places, whether such would not be the result. My opinion is, that there would be as much vegetation and as many insects as from those waters.

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91. On the whole, from your consideration of the subject, you think the Thames would probably be the source from which to derive the additional supply to the metropolis?—For this reason, as well as others, that where there is such a river there is an inexhaustible supply; and there are so many instances where, having started with a limited supply, the inhabitants have experienced considerable inconvenience from a deficiency, that I do not think it would be desirable to look for a supply from any source but a large river. I have recently examined a specimen of spring-water from the neighbourhood of Watford, with which it has been proposed to supply a part of the metropolis. I found this water about 17° of hardness. By the lime process it was reduced to 3° . It seems a very wholesome and pleasant-tasted water, and is remarkably free from organic matter. I found it to contain a trace of nitrates, which I hold to be a very strong presumption, that whatever portion of organic matter it may have originally held, that matter has undergone a complete change. I could not find in it any trace of ammonia, which occurs very frequently, or at least may easily be produced, in the organic matter of drainage water. Of course I can give no opinion whatever as to the quantity of such water that may be obtained, nor of the engineering advantages or disadvantages that might be peculiar to this source of supply; but I think very favourably of the quality, which may be compared to the springs that supply the Thames.

92. You contemplate the alteration of the Thames water by the process you refer to, not by taking it at a higher source?—Applying the process, you get the Thames and the New River, and probably most other rivers within reach of London, so slightly different when they are purified, that it is as well to take what you have in abundance and at hand.

93. If that be the case, and by the application of the process you speak of they are brought to the same degree of improvement, would it not be best to take that water which can be procured the cheapest?—Certainly.

94. Are you to be understood that, notwithstanding your process, a considerable quantity of animal and vegetable matter would still remain in solution?—Not a considerable quantity; the greatest part goes down, and goes down manifestly too, immediately.

95. To that portion which would remain, you would not attach much importance in reference to the public health?—Not much. Still, if it were possible to remove what little remains by any easy and cheap process I knew of, I would propose its removal.

96. Have you any farther suggestion to offer relating to water?—There is one point I will take the liberty of suggesting to the Commissioners, and it is this, I think it would be of prodigious public service if an examination were made by some gentleman in the Commission of the pipe waters, and the favourite wells in use in the principal towns in England. It is now so very easy to come into communication with persons having projects for bringing water into towns, that I am aware from experience, how important it is to possess a general knowledge of the qualities of water such as is usually elsewhere supplied, as well as the qualities of the water that is the subject of the project, and of

other accessible waters in the immediate vicinity. Formerly, that would have occasioned an enormous expense; but now, the hardness can be taken in less than an hour; the alkalinity would not take more than two hours in any case, and I am quite sure that a general examination of the principal waters in use in the towns of England would be of great value to the public. I am quite sure it would be an important undertaking on behalf of the public. As a motive for the undertaking, I may mention the degree of accuracy that can be attained in the process of ascertaining the total earthy matter present in any water in so short a time. I have frequently taken the hardness of London waters at the University College. Supposing the hardness of the water were 14° , we operate in this process not on a whole gallon, but only on the 70th part of a gallon, containing $\frac{1}{70}$ ths, or $\frac{1}{5}$ th of a grain. In repeating this experiment, we can come to within $\frac{1}{10}$ th; that is to say, if the experiment be performed with ordinary care, the highest result will not be more than $14\frac{1}{10}$ ths, nor the lowest lower than $13\frac{9}{10}$ ths. Thus, you may repeat the experiment so as to ascertain within the 140th part of the $\frac{1}{5}$ th of a grain; that is, the 700th part of a grain. In regard to comparative results in quantity, there is this other reason: a great many analyses were formerly made of the Thames water and other waters in the neighbourhood of London. Some of the Commissioners will be able to appreciate this consideration. Different methods have been employed by different chemists. I am quite sure that any competent scientific chemist, taking all the analyses together, will find that the results are valuable only in such analyses, or chiefly in such analyses, as have been performed by the same chemist. You cannot compare the result of the analysis by A. B. of one water, with the result of the analysis by C. D. of another water; although you may safely compare with each other the analyses of two waters by A. B., or of two by C. D. But the new processes for the testing of waters start from solutions so easy to be made, and the operations are so easy and simple, that you may look with confidence to uniform results, by whosoever hands performed. The results will thus always afford an easy and accurate means of comparing different waters with each other or of comparing the same water with itself at different seasons.

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[The Witness gave in the following note in writing as an addition to his Evidence.]

Living in a town with a population of nearly 70,000 inhabitants, where the water is supplied, not by a joint stock company, but by the Commissioners of Police, who are elected by the rate-payers, it has often occurred to me to question the policy of allowing water to be supplied to a town by a joint-stock company in any case whatsoever. The extensive pipes laid throughout all the streets, and branching to most of the houses, cannot conveniently, nor without a great sacrifice of expense, be laid in a second set, much less in a third; therefore competition, such as occurs in the supply of bread and meat, or of like articles of demand, is out of the question in regard to the supply of water on a large scale. The establishing of a joint-stock company for the supply of a town with water, is the establishing a monopoly of

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trading persons, having the power, without responsibility, of taxing the inhabitants for their own benefit. The practical check on any crying excess in their charge, and on their heedlessness about supplying water of a proper quality, lies mainly in the apprehension of a second company being established; but since no new works can be established without an Act of Parliament, and without risk of competition with the old company, such as almost always proves ruinous to both; and since, in order to establish the new company, an agitation in the community has to take place, the check is not of a desirable kind; neither is it effectual in the generality of cases. There is no town that I know supplied with so good water as Aberdeen, or having the supply managed in a more satisfactory manner. The gas-works there are the property of a joint-stock company, and although there is as little reason to complain of that company as there can be of any joint-stock company situated in like circumstances, still there is a strong feeling of regret among my townsmen, that the free revenue derived from the gas should go to the pockets of trading monopolists rather than to the revenue of the town, and that the gas is not, like the water, under the direction of the Police Commissioners.

T. C.

John Thomas Cooper, Esq., examined.

Mr. Cooper.

1. With your practice you have examined a great number of different waters?—I have during the last 25 or 30 years been actively engaged in the examination and analysis of water of various kinds and qualities; that is to say, of what are termed mineral waters, such as are used for medical purposes, of ordinary spring, river, and pond waters, as regards their fitness for employment and use by manufacturers; and very frequently, indeed, by individuals residing in the country, about to supply their mansions or dwellings with water for domestic purposes. In the latter case I have frequently had three, four, or more specimens sent me, to report upon and to recommend that which, in my opinion, has appeared to me the best, under all the circumstances of the case, to be adopted for use.

2. You have analyzed the water of the Thames?—I have repeatedly analyzed the water of the Thames, taken at several places and at various seasons, the highest point being at Windsor; the lowest, the entrance to the Surrey Canal.

3. What is the general character of your analysis?—The results of my examinations and analysis, as regards the contamination (if it may be so termed) of the Thames water with mineral matter, from whatever point it was taken, does not materially differ; that is to say, about 20 grains (sometimes a grain or two more or less) of solid mineral matter I have obtained from a gallon of it by careful evaporation to dryness; and it seems to me, from long experience in the use of this water, that the sulphate of lime which it invariably contains, is the mineral ingredient that varies the most in quantity; being in some cases as low as about one grain, in others as high as nearly three grains in a gallon.

It is to this impregnation, and to the carbonate of lime, which is always present in it, to the amount of about 16 or 17 grains in a gallon, that the hardness, as it is termed, is to be attributed: that these calcareous matters are variable, every one who has used the Thames water for ablution must have had ample experience. Three substances constitute the principle of the mineral impregnations; there is, however, beside these a small quantity of common salt; a still smaller amount of a magnesian salt; some silica, and occasionally oxid iron in very minute quantities, with variable quantities of organic matter.

4. Is not the quality of the water a good deal affected by the nature of the atmosphere to which it is exposed?

5. Have you any doubt that water exposed to an impure atmosphere is capable of absorbing its impurities and this becoming noxious.

Ans. 4 and 5. I can have no doubt whatever that from the known tendency of water to imbibe odours and taints of any kind from exposure to their influence, but that water subjected to the impure atmosphere of any crowded situation, rendered more impure from deficient ventilation, that it will become in proportion to the surface exposed, and the length of time of exposure, sufficiently imbued with matter, not cognizable to the chemist, but palpably recognizable to the senses, as to be unpalatable, and, no doubt, unwholesome.

6. Can you give any instances in which this has happened, and any illustrations of the effects upon the living system and upon the health? —I do not at this time recollect any instance of the kind to which you allude.

7. Besides the chemical analysis of water, have you attended to the amount of organic matter contained in it in different instances?—The amount in weight of organic matter contained at any time in any natural water is always very small, but, in my estimation, is not on that account to be disregarded; it is notorious that filtered Thames water when taken on board ship in a short time becomes putrid and unfit for use; this is only to be attributed to the presence of organic matter originally existing in the water reacting on the sulphate of lime, or any other sulphate it may contain, thereby engendering the production of sulphuretted hydrogen; then, as soon as the whole of the organic matter has become decomposed, the sulphuretted hydrogen partly escapes into the atmosphere by the exposure of the water to its influence, and any that may remain in the water becomes in the course of time, by the absorption of atmospheric oxygen, sufficiently oxidized as not to be distinguished. While on this subject I may relate a circumstance that occurred about two years since in my own laboratory. I have a still that is used for no other purpose than distilling water; the accumulated bottoms of a number of distillations were accidentally suffered to boil to dryness, and became subsequently heated to that extent that decomposition of them was effected; the stench produced by the decomposition of the organic matter was peculiar, and not to be mistaken as that resulting from animal produce, and so persistent was it as to infect the produce of many subsequent distillations, although every care was taken to cleanse the still and its appurtenances almost immediately after the occurrence.

8. With reference to the influence of water on health, do you not think that an inquiry into the quantity of organic matter contained in

Mr. Cooper. it, is as necessary as an inquiry into its chemical properties?—I am
 ———— decidedly of opinion that an inquiry into the amount of organic matter in any water intended for domestic employment is of equal, if not of greater importance, than the deterioration of what is usually termed the saline or chemical constituents, which latter, as I have already stated, does not generally exceed 20 grains in a gallon of the water of the Thames, and these ingredients being comparatively if not wholly inert in their action on the human system, when taken internally, even suppose the whole gallon to be imbibed in the course of the day; it is nevertheless true, that in an economical point of view as regards the saving of soap, or extracting a better infusion from malt, as in brewing, or for the purposes of the tea-table, in obtaining a better infusion in the tea-pot from an equal quantity of tea, a water containing the smallest amount of calcareous salts is to be preferred; but these matters I hold to be of comparatively little importance when we have under consideration the question as to what kind of water ought a city or town to be supplied with, to give to the inhabitants of all grades in society all the advantages as regards health and economy in its employment? If this question were to be put directly to me, I should answer, The water obtained from the chalk stratum underneath us in London appears to me to possess every requisite for domestic employment; that is to say, it is comparatively free from calcareous salts, also from any organic matter liable to suffer decomposition or become putrid, and it is exceedingly soft from its containing a notable quantity of carbonate of soda, thereby it possesses the property of economising soap in washing, and would enable us to obtain in all cases a better extract from any material exposed to its action, either when used hot or cold. I am free to confess that I take the Artesian well water, such as that of Trafalgar-square (which I have very carefully analyzed), and that also of Her Majesty's Mint, as the beau ideal of what a water ought to be for the supply of a city or town, but as there are places in great number out of the reach of such a supply, I can only then say, take the water of Trafalgar-square as the standard of comparison, and select that which approximates to it the nearest in all its qualities.

9. What are the chief conditions which influence the greater or less contamination of water with organic matter?—The drainage of London and the tidal influence.

10. What is your opinion as to the value of Thames water as a supply for the metropolis; say, at Battersea, at Chelsea, and at London Bridge?—I am of opinion that neither of the places to which allusion has been made are proper places from which water ought to be taken, inasmuch as they are all within the influence of the tide; consequently the influx of organic matter from the drainage of the town, which is constant, is, in fact, never got rid of, but I am of opinion is continually on the increase.

11. What is your opinion as to the value of Artesian wells as a source of supply with reference particularly to the quantity and quality of the water thus to be obtained?—I consider I have already replied to one of the questions propounded, that as respects the quality of the Artesian-well water; and as to the quantity capable of being afforded by wells, it, of course, must as yet be a matter of speculation; but I

gave that matter, in conjunction with some others, a good deal of consideration about 14 years since, and I came then to the conclusion that an abundant supply was obtainable, since which period I have had no reason to alter the opinion I then formed, but, on the contrary, all that I have since learned has confirmed it.

12. You were called upon to examine the water of the Surrey Canal. Will you state the result of your examination?—It is, to the best of my recollection, 15 or 20 years since I was called upon by a Water Company on the south side of the river to examine the water of the Surrey Canal. This I did by taking specimens at several points between its entrance at Rotherhithe and its termination at Camberwell. The results of that examination showed an increase of specific gravity, a corresponding increase of saline matters, and also of organic matters, from its entrance to its termination, attributable, no doubt, on the one hand to evaporation by atmospheric influence, and on the other to its stagnation or comparatively small change it undergoes by the traverse of barges.

13. Have you attended to the question of the constant as compared with the intermittent mode of supply?

14. Do you conceive there would be any difficulty in applying the system of constant supply to the metropolis?

15. What do you conceive to be the peculiar advantages of the constant mode of supply?—One of the advantages of a constant supply, I conceive, will be more in favour of the poorer class of consumers than the richer; for as the poor have but little convenience for storing up the quantity of water they may require for their use from day to day, and if they had, there is a probability of its becoming more or less contaminated by being kept in their too much crowded dwellings; while those who are better to do in the world are well provided with well constructed receptacles, where it may be (if sufficient precautions are taken) retained for a time without undergoing any material change.

16. What in your opinion are the disadvantages?—I am not aware of any disadvantage.

17. Have you observed any instances of the contamination of water by its retention in tanks, cisterns, and butts?—I know of many instances: some in my own premises, and others in those of my friends, where the Thames water with which they are supplied has, in my cisterns and in theirs, become unfit for use, and the supply-pipes occasionally been stopped up, by decaying or decayed confervæ.

18. Do you think that contaminations may take place to such an extent as to prove injurious to health?—If the imbibition into the human system of decaying vegetable or animal matter be injurious to health, which I believe is agreed on all hands to be the case, it must follow as a consequence that, if water becomes in any degree contaminated by putrescent matter from any cause whatever, that in proportion as the amount of decaying matter of either kind may be increased, so will the insalubrity of the water be increased also.

19. What is your opinion of the practice of exposing water in these receptacles for domestic purposes, in the close and dirty yards and courts in the poorer districts of the metropolis?

20. Have you known any instances of injurious effects from this cause during the prevalence of epidemics or otherwise?

Mr. Cooper.

21. What is your observation of the Company's water which you receive at your own residence?—It frequently comes in tainted with the smell of decaying animal or vegetable matter; it having, in fact, a slightly putrescent smell and taste.

22. Is it delivered filtered, or free from matter in suspension?—It comes in much clearer than it used to do, and deposits very little matter in the bottoms of the vessels in which it is detained. I think it more likely that it is cleared by subsidence, than by filtration.

23. Do you filter the water you use?—Yes, we filter all the water we use for culinary purposes.

24. Are we to understand then that the smell you speak of is perceptible even after filtration?—Yes.

25. It is, perhaps, superfluous to ask you, as a chemist, whether you consider that this is a water which ought to be supplied to a population?—I certainly think not.

26. What description of filter do you use?—One made of finely powdered glass, and animal charcoal; one stratum of about half an inch thickness of finely powdered glass; upon which is a layer of about an inch and a half of well burnt animal charcoal, and over this about three quarters of an inch to an inch of more coarsely pounded glass, and over that, the usual sponge for filters. This I conceive is a mechanical as well as a chemical filter.

27. How does it act?—Very well.

28. But it does not yet detain the matter in solution to which you attribute the disagreeable smell?—No; but I believe it diminishes it.

29. Are there not natural filters which do detain matter in solution?—Yes; for instance, water which is impregnated with the water draining from bogs which is of a pale brown colour when taken up in a glass, and looks like an infusion of tea when in the river, is rendered quite colourless by percolation, through a stratum of sand and gravel, in which vegetation is going on; and whether the decolouration from the effects of vegetation, or from the peculiar composition of the filter or percolate, I am unable to decide; but I rather give evidence to the effect of vegetation, seeing that no artificially constructed filter yet made will effect the object.

Professor Hoffman, examined.

Professor Hoffman.

1. You are Principal of the College of Chemistry?—I am Professor in the Royal College of Chemistry.

2. You were educated under Baron Liebig?—I was.

3. In the course of your operations at the College, have you had occasion to make or superintend analysis of the Thames water? and, if so, will you be so good as to communicate to the Commission a copy of the results of the several analyses?—I send with this copies of the results of these analyses.

4. At what places and at what times were the specimens taken?—It is stated in the copies of the several analyses.

5. It is presumed as a matter of course that the quality of the water of such a river as the Thames will vary at different times and seasons, according as upland floods may bring surface water, or as the river

may be left to its ordinary sources of deep springs (if such be the sources), and according to the character of the districts from which the floods may come?—It cannot be doubted that the quality of the water of such a river as the Thames must vary within certain limits, according to the seasons, and that it may be occasionally influenced by upland floods; and this influence must vary with the character of the district from which the floods may come.

6. Will you state to the Commissioners the extent to which, from your knowledge, the analysis of river waters or springs has been attended to on the Continent, and put in evidence any information you may have collected of the results of any such analysis?—In reply to this question, I beg to offer to the Commissioners a copy of a synopsis (intended for publication in the Annual Report on the progress of Chemistry), of all the analyses of river-waters and well-waters which have been made, during 1847 and 1848, in this country, in America, and on the Continent.

7. It is presumed that the quality of a water will be affected by the extent to which it absorbs or gives out the various gases that it may come in contact with?—Most undoubtedly, especially with regard to the gases which water gives out. I may mention that I know a little river in the north of Germany, the water of which is found to be very hard when examined close to its source in the limestone. This water becomes softer and softer the further it proceeds in its course; this diminution of hardness, which has been traced by analysis, is evidently due to the gradual loss of carbonic acid, which retained a certain quantity of carbonate of lime in solution. Clark finds Watford water softens about one-fourth of a degree per day by exposure in a shallow dish.

8. In respect to the quality of the air of the atmosphere itself, it is observed that a child taken from a mountain district in the country, and placed in a close court or alley in a densely populated town-district, will lose its healthy colour, and no longer thrive at the same rate, although its condition in other respects may remain the same. Is not this a test of the difference between one atmosphere and another as decisive as litmus paper for an acid or alkaline solution?

9. Has chemistry been able to determine the agencies in local atmospheres which produce such effects as are thus universally experienced in the young, susceptible, feeble, and sickly?

Ans. to 8 and 9. It cannot be denied that the air in the close courts and alleys of a densely populated town-district produces effects upon the organism which are not observed, *e. g.*, in a mountainous country. These effects may, to a very considerable extent, be due to the difference in the physical and mechanical condition, state of motion, rapidity of change, &c., of the two kinds of air in question; nevertheless, part of these effects may, I believe, be ascribed to the presence of certain constituents which the air contains, in addition to its usual components. These constituents must be present, however, in exceedingly small quantity, for chemistry has not, up to the present moment, succeeded in isolating these substances, or characterizing them by particular reactions. As yet, in the air only the presence of oxygen, nitrogen, aqueous vapour, carbonic acid, and ammonia, has been accurately

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established, but it has been proved that occasionally other substances must exist in the atmosphere; for, on passing the air of certain localities through concentrated sulphuric acid, the acid is found to become black; an effect which is not produced by any of the constituents mentioned above. Thus the presence of substances other than those enumerated is indicated only by their action upon the organism and upon sulphuric acid, but we are unable to say whether both kinds of atmospheric constituents are the same.

10. You must have had experience of a London fog: has chemistry the power of analyzing its constituents?—The experiment has never been tried; but, although I think that it would not be difficult to condense aqueous vapour, and to collect finely-divided carbon, and various products of the combustion of coal, from a London fog, on submitting a sufficient quantity of the foggy air to analysis, I am not prepared to say whether there are not at such periods minute quantities of certain constituents in the atmosphere, for the detection of which science is not sufficiently advanced, and which, in this respect, would resemble the additional air-constituents supposed to exist in the atmosphere of densely populated cities.

11. Since it is a matter of common experience that water absorbs a quantity of the air which sweeps over it, or in which it is confined, it would follow that it may absorb matter of which chemistry has not yet determined the essential properties?—Most of the gases having been found to dissolve to a certain extent in water,* it is very probable that the atmospheric constituents referred to are likewise soluble in water. This question, however, cannot be positively decided as long as we have not become more fully acquainted with the nature of these substances.

12. Will you state whether there are any, and what, results of chemical research available for practical guidance in respect to the collection, storage, and distribution of water?

13. Are you aware of any, and what, observations on waters of different sorts—as to their value for drinking, washing, and for culinary purposes—in Germany or other parts of the Continent?

Ans. to 12 and 13. With respect to questions 12 and 13, I beg to remark that I am not in possession of any knowledge beyond that derived from ordinary chemical experience.

The properties requisite in waters intended for drinking, washing, and for culinary purposes, vary to a very considerable extent. Whilst a certain quantity of lime and magnesia-salts will, with a few exceptions perhaps, not be found inconvenient in water intended for drinking, these salts interfere sadly with its application for washing and for culinary purposes. Again, the soft, slightly alkaline water, well calculated for the latter purposes, will be found very insipid and disagreeable when used as a drink. If the *same water* is to be used for the *three*

* 1,000 gallons of water dissolve, at the common temperature—

46 gallons of oxygen.

25 gallons of nitrogen.

2,500 gallons of sulphuretted hydrogen.

1,000 gallons of carbonic acid.

500,000 gallons of ammonia.

different purposes, I believe that it would be advantageous to collect springs resembling in their composition as closely as possible rain-water, which is adapted for drinking, washing, and for all kinds of culinary purposes. Among various waters, containing, *cæteris paribus*, different quantities of fixed constituents, I would give the preference to the water containing the smallest amount. For the storage of the water, I would recommend cisterns of slate, and for the distribution, earthenware or glass pipes; lead being acted upon by very pure water. An article has been lately introduced under the name of Paris vitrified iron, the application of which for the distribution of water appears very promising; a series of experiments with this material are not unlikely to lead to important results.

On the Continent, the water question has been discussed far less than in this country, and I am not aware of any results which would be worth the notice of the Board.

Analysis of Thames-water.

The Thames water was analysed by Mr. F. Clark and by Mr. E. T. Bennett. The former took the water in the neighbourhood of Twickenham on the 16th December, 1847, two hours after high tide. His results are contained in "Analysis of Rain-water, River-water, and Well-water," page 4.

Mr. Bennett took the water from the middle of the river, opposite the Hospital at Greenwich, on the 1st January, 1849, at high tide.

His results are given in the annexed Table:—

	Grains in an Imperial Gallon.
Sulphate of potassa	1·3710
Sulphate of soda	3·9224
Sulphate of magnesia	0·5475
Chloride of magnesium	1·1482
Chloride of calcium	1·6272
Carbonate of lime	14·3997
Silicic acid	0·7958
Phosphate of alumina (iron)	Traces.
Organic matter	4·0810
	27·8928

Free carbonic acid 19·8535 cubic inches in the gallon.

Analysis of Rain-water, River-water, and Well-water.

According to *R. A. Smith*, rain-water falling in towns contains organic matter exceeding usually 0·001 per cent. (in *Manchester*). Rain-water, collected after 30 hours' rain, was found to contain 0·0027 per cent. of chlorine and 0·00343 of sulphuric acid. *Smith* frequently found the rain-water alkaline, which he thinks is due to carbonate of ammonia, and the air frequently acid. Water from peaty soil contains a substance which, on burning, exhibits the odour of peat. The river *Dee*, near *Chester*, contains 25 grains of such organic matter per gallon. River-water in the neighbourhood of large towns leaves a residue which, on burning, exhibits the odour of protein-compounds

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in a state of decomposition. In well-water at *Manchester* he found as much as 14 grains of organic matter and ammonia-salts, and 70 grains of nitrates per gallon.

Ragsky has examined the water of two artesian wells in *Vienna*; (A) of that near the *Mariahilf* line, and (B) of that at the station of the *Vienna Raab* Railway. Column (C) gives an abstract of *Johnstrug's* analysis of the *Copenhagen* well-water. (A) represents the quantities in *Vienna* grains referred to 16 oz. of water; in (B) and (C) the quantities are referred to 1000 parts of water.

	A.	B.	C.
Carbonate of Lime	2.800	0.0078	2.68 to 5.13
„ Magnesia	0.694	0.0043	0.19 to 0.61
„ Soda	.	0.6387	.
„ Protoxide of Iron	0.010	0.0010	.
Chloride of Potassium	.	.	} 0.51 to 7.21
„ Sodium	.	0.2893	
„ Calcium	0.099	.	.
„ Magnesium	1.553	.	0.26 to 0.75
Sulphate of Potassa	.	.	0 to 0.75
„ Lime	1.979	.	0.09 to 0.88
Nitrate of Soda, with some Potassa	0.977	.	.
„ Magnesia	1.155	.	.
Phosphate of Lime	.	.	0.07 to 0.39
Silicic Acid	0.132	0.0122	0.18 to 0.31
Loss and Organic Substance	0.146	0.0237	.
Volatile Compounds	.	.	0 to 0.60
Free Carbonic Acid	2.18	.	.

Müller has analysed the water of the river *Meuse*, of several wells in *Rotterdam*, of the *North Sea* at *Scheveningen*, of the *Rhine* near *Emmerich*. He gives the amount of fixed constituents, without stating what sort of lbs. is adopted, and in which unit the various weights are expressed; we consequently refrain from details.

Boutron-Charlard and *O. Henry* have examined the various waters which feed the public wells of *Paris*. This investigation embraces specimens of *Seine* water collected at the *Pont d'Ivry* (A), at the *Pont Notre Dame* (B), at the *Pompe du Gros Caillou* (C), at the *Pompe de Chaillot* (D), the water of the *Marne* (E), the water coming from *Arcueil* (F), the water of the *Artesian well* at *Grenelle* (G), the water of the *Canal de l'Ourcq* (H). The Table gives the number of grammes of solid constituents, and the number of litres of gas, contained in one litre of water. (See page 191.)

Déville has examined the composition of the following waters: of the *Garonne* near *Toulouse* (A), of the *Seine* near *Bercy* (B), of the *Rhine* near *Strasburg* (C), of the *Loire* near *Orleans* (D), of the *Rhone* near *Geneva* (E), of the *Doubs* near *Rivotte* (F), of the well-water of *Mouillère* (G), of *Billecul* (H), of *Arcier* (I), and of *Bregille* (K) near *Besançon*, of *Suzon* (L) near *Dijon*, and of *Arcueil* (M) near *Paris*, of the wells in the *Grand Rue* (N), the *Rue de la Préfecture* (O), and near the *Faculté des Sciences* (P) at *Besançon*.

He determined not only the composition of the whole water, but also that of the precipitate produced by one hour's ebullition, and of

	A.	B.	C.	D.	E.	F.	G.	H.
Bicarbonate of Lime	0·132	0·174	0·229	0·230	0·301	0·158	0·092	0·158
„ Magnesia	0·060	0·062	0·075	0·076	0·120	0·060	0·092	0·075
„ Potassa	..	..	..	..	..	Trace.	0·0100	..
Sulphate of Lime	0·020	0·039	0·040	0·040	0·022	0·138	..	0·030
„ Magnesia	0·010	0·017	0·027	0·030	0·018	0·072	..	0·095
„ Soda								
„ Potassa								
Chloride of Calcium	..	..	..	..	..	..	0·0320	..
„ Magnesium	0·010	0·025	0·032	0·032	0·020	0·081	..	0·113
„ Sodium								
„ Potassium								
Potassa-Salts	Trace.	Trace.	Trace.	Trace.	..	..	..	..
Alkaline Nitrates	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	..	Trace.
Silicic Acid	0·008	0·014	0·023	0·024	0·030	0·018	0·0100 0·0020	0·069
Alumina								
Sesquioxide of Iron								
Organic Matter	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.
Total Amount of fixed Con- stituents	0·240	0·331	0·426	0·432	0·511	0·527	0·1494	0·590
Atmospheric Air	0·003	0·003	0·004	0·003	Trace.	0·004	..	..
Free Carbonic Acid	0·013	0·014	0·014	0·013	0·013	0·070	..	..

the soluble and insoluble portion of the residue left on evaporation. We here give his results respecting the composition of the water as a whole. The following Table represents in milligrammes the amount of fixed constituents, and in cubic centimetres that of the free gases (assumed to be dry), of a temperature of 0° and a pressure of 760 milligrammes, contained in 10 litres of water. The same holds good for *Grange's* analysis of the water of the *Isere* near *Grenoble*. *Grange* has examined, moreover, the water of several brooks of the *Isere* valley. He gives the composition of these brooks, which run over soils of varying composition in various stages of their course, and discusses the dependance of the amount of fixed constituents on the geological formation of the soil; he adduces the presence, in spring-water, of magnesia salts as the cause of goitre and rhachitism, &c.

	A.	B.	C.	D.	E.	F.	G.	H.
Silicic Acid	401	244	488	406	238	159	250	246
Alumina	..	5	25	71	39	21	43	43
Sesquioxide of Iron	31	25	58	55	..	30	..	..
Carbonate of Lime	645	1,655	1,356	481	789	1,910	2,573	2,561
„ Magnesia	34	27	50	61	49	23	..	46
„ Protoxide Manganese	30	..	..	..	..	..	..	..
Sulphate of Lime	..	269	147	..	466	..	51	100
„ Magnesia	..	..	..	..	63	..	..	..
Chloride of Calcium	..	..	..	..	..	..	7	71
„ Magnesium	..	..	..	..	..	5	20	40
„ Sodium	32	123	20	48	17	23	..	..
Sesquicarbonate of Soda	65	..	..	..	..	..	..	..
Carbonate of Soda	..	..	..	146	..	..	..	..
Sulphate of Soda	53	..	135	34	74	51	..	..
„ Potassa	76	50	..	..	..	..	..	..
Nitrate of Potassa	..	..	38	..	40	41	23	44
„ Soda	..	94	..	..	45	39	118	156
„ Magnesia	..	52	..	..	..	..	..	..
„ Lime	..	..	..	..	..	..	..	..
Silicate of Potassa	..	..	..	44	..	..	..	..
Total Amount of fixed Con- stituents	1,367	2,544	2,317	1,346	1,820	2,302	3,085	3,307
Free Carbonic Acid	170	162	76	18	79	178	390	267
Nitrogen	79	120	159	202	184	182	154	101
Oxygen	157	39	74					

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	I.	K.	L.	M.	N.	O.	P.	Q.
Silicic Acid	390	348	152	306	314	297	551	37
Alumina	90	65	10	53	94	62	39	35
Sesquioxide of Iron	..	..	..	..	..	..	..	..
Carbonate of Lime	2,139	2,079	2,300	1,990	2,156	2,017	2,331	1,037
,, Magnesia	78	43	38	82	85	207	76	25
,, Protoxide Manganese	..	..	..	..	..	..	..	..
Sulphate of Lime	..	74	..	1,638	802	662	2,660	208
,, Magnesia	..	..	..	..	..	..	..	302
Chloride of Calcium	..	11	..	..	..	238	199	..
,, Magnesium	..	27	..	166	72	255	615	7
,, Sodium	20	..	32	376	557	15	..	36
Sesquicarbonate of Soda	..	..	..	..	..	..	..	..
Carbonate of Soda	69	..	21	..	..	..	..	..
Sulphate of Soda	45	..	27	54	..	..	..	..
,, Potassa	..	..	..	201	57	..	..	} 90
Nitrate of Potassa	Trace.	23	27	..	899	786	535	..
,, Soda	..	48	..	..	304	870	1,229	..
,, Magnesia	..	..	..	570	..	..	..	..
,, Lime	..	81	..	..	..	..	381	..
Silicate of Potassa	..	..	..	..	..	..	..	..
Total Amount of fixed Con- stituents	2,831	2,799	2,607	5,436	5,340	5,410	8,616	1,876
Free Carbonic Acid	208	226	237	256	202	263	350	110
Nitrogen	153	142	167	127	171	157	202	} 30
Oxygen	59	72	75	50	43	41	44	}

Clark has examined the *Thames* water near *Twickenham* (A); *Abel* and *Rowney* that of the artesian well in *Trafalgar-square*, in *London*, which comes from a depth of 400 feet, and is remarkable for its softness (B). In the following Table we give the quantity of fixed constituents, expressed in grains and in grammes, the amount of free carbonic acid, expressed in English cubic inches and in cubic centimetres, contained respectively in an imperial gallon and in 10,000 grammes of water. In the analysis of a well-water of *Wolverton* (C), by *Giles*, and of the river *Exe*, near *Exeter* (D), the quantities are expressed in grains, and referred to one gallon (70,000 grains).

	A.		B.		C.	D.
	Grains.	Grammes.	Grains.	Grammes.		
Specific gravity	1.0003	1.0003	1.00009	1.00009	1.00067	..
Sulphate of Potassa	0.66794	0.09542	13.6710	1.95300	..	0.0807
,, Soda	2.00011	0.28573	8.7493	1.24990	14.324	3.040
,, Lime	0.45073	0.06439	..	..	..	0.160
,, Magnesia	..	..	..	..	..	0.640
Chloride of Magnesium	..	..	..	..	..	Trace.
,, Calcium	1.75021	0.25003	..	..	..	4.240
,, Sodium	..	..	20.0585	2.86550	6.003	0.896
Carbonate of Lime	12.75946	1.82278	3.2550	0.46500	10.9650	0.064
,, Magnesia	1.02711	0.14673	2.2540	0.32200	2.319	..
,, Soda	..	..	18.0488	2.57840	6.576	0.160
Nitrate of Lime	..	..	..	..	..	..
Phosphoric Acid	Trace.	Trace.	..	..	..	..
Phosphate of Soda	..	..	0.2910	0.04160	..	..
,, Lime	..	..	0.0340	0.00486	..	Trace.
,, Iron	..	..	..	..	0.540	..
Oxenate of Magnesia	..	..	..	..	..	Trace.
Orenic Acid	..	..	0.1372	0.01960	..	..
Apocrenic Acid	..	..	0.0927	0.01410	..	..
Organic Matter	3.48019	0.49717	0.6720	0.09600	2.850	1.60
Sesquioxide of Iron	Trace.	Trace.	..	..	..	..
Alumina	Trace.	Trace.	..	..	0.260	..
Silicic Acid	0.27314	0.03902	0.9710	0.13100	0.200	Trace.
Loss	0.07106	0.01158	1.1644	0.17404	..	..
Total Amount of fixed Consti- tuents	22.48995	3.21285	69.4050	9.91500	44.032	10.880
Free Carbonic Acid	14.233	51.34	8.423	303.9	..	..

Bull has examined the waters, remarkable for their hardness, of various wells at *Hartford* in *Connecticut*, in *North America*. He found in 10,000 parts, by weight of water :—

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	A.	B.	C.	D.	E.
Specific Gravity	1·0008	1·0004	1·0001	1·0008	1·0011
Sulphate of Lime	0·69	0·61	0·30	0·79	0·89
Chloride of Magnesium	0·41	0·23	0·22	0·81	0·41
„ Calcium	1·12	0·70	0·39	..	1·79
„ Sodium	1·91	..	..	..	2·67
Carbonate of Lime	2·25	1·31	0·21	1·48	..
„ Magnesia	0·19	..	..	..	1·57
Crenate of Magnesia	..	0·13	0·76	0·44	..
Carbonate of Soda, equivalent to } Crenate }	0·22	1·09	1·19	2·35	2·67
Sesquioxide of Iron	0·04	0·38	{ 0·14 }	0·04	Trace.
Alumina	..	..		0·23	..
Lime	0·18	0·60	0·14	0·04	0·10
Silicic Acid	0·10	0·46	..	0·18	1·78
Loss					
Total Amount of fixed Con- } stituents }	7·11	5·51	3·31	6·36	11·82

ANSWERS to QUESTIONS put to R. PHILLIPS, Esq.

Mr. Phillips.

- 1. You are one of the Government chemists attached to the department of the Geological Survey?—I am chemist and curator at the Museum of Practical Geology, which is a Government establishment.
- 2. In the course of your practice, public or private, have you been called upon to analyze Thames water?—I have been frequently so called upon.
- 3. How often?—I cannot answer this question without referring back to the operations of many years, which I am apprehensive I may be unable to find an account of.
- 4. Will you be so good as to state whether you have found the results to differ very materially at different places and times?—I think not very materially, unless the water be taken very high up the river. This will appear by the result of the analyses, which I will now state :—

The first analysis of which I retain a record was reported to the Commissioners of 1827.
The water was taken from the north reservoir at Paddington, in May, 1827.
An imperial gallon gave $\frac{4}{10}$ of a grain of mechanically suspended impurity.
The saline contents of a gallon, obtained by evaporation to dryness, weighed 24·4 grains, consisting of—

Carbonate of lime	16·4	grains
Sulphate of lime	6·0	„
Common salt	2·0	„
	24·4	„

Mr. Phillips. I may here remark, once for all, that Thames water also contains minute traces of magnesia, silica, oxide of iron, and organic matter. The gallon is in all cases the *imperial*.

Thames Water taken from the House Cistern of the Burlington Hotel when the Water was on, May 1827.

A gallon gave 0·4 grain of suspended impurity.

A gallon, evaporated to dryness, left 22·8 grains of residue.

The 22·8 grains consisted of—

Carbonate of lime	.	.	15·8	grains
Sulphate of lime	.	.	5·6	„
Common salt	.	.	1·4	„
			22·8	„

Thames Water taken from the Lock above the Waste Weir at Teddington, April 29, 1827.

A gallon gave 0·3 grain of suspended impurity.

A gallon, evaporated to dryness, left 17·4 grains residue.

The 17·4 grains consisted of—

Carbonate of lime	.	.	14·8	grains
Sulphate of lime	.	.	1·2	„
Common salt	.	.	1·4	„
			17·4	„

It will be observed that this water, taken far up the river, contained only about two-thirds as much saline matter as that from the north reservoir at Paddington.

Thames Water from the West Middlesex Water-works, brought to me by a Messenger from the Office of Woods.

A gallon, evaporated to dryness, left 20·4 grains residue.

The 20·4 grains consisted of—

Carbonate of lime	.	.	15·0	grains
Sulphate of lime and common salt	.	.	5·4	„
			20·4	„

N.B. The common salt may generally be considered as equal to about one-half the quantity of sulphate of lime.

Thames Water from the Grand Junction Source, reported to the Lords' Committee, March 1840.

A gallon gave 0·28 grain of suspended impurity.

One gallon, evaporated to dryness, left residue 19·4 grains.

The 19·4 grains consisted of—

Carbonate of lime	.	.	16·0	grains
Sulphate of lime and common salt	.	.	3·4	„
			19·4	„

Analyses of Thames Water supplied from different Works. 195

Thames Water delivered in London by the Grand Junction.

Mr. Phillips.

A gallon, evaporated to dryness, left residue 19·8 grains.

The 19·8 grains consisted of—

Carbonate of lime	16·0 grains
Sulphate of lime and common salt	3·8 „
	19·8 „

Thames Water from the River opposite the Works of the West Middlesex.

A gallon gave very nearly 0·3 grain of suspended impurity.

A gallon gave, by evaporation to dryness, 18·6 grains residue.

The 18·6 grains were composed of—

Carbonate of lime	16·9 grains
Sulphate of lime and common salt	1·7 „
	18·6 „

Thames Water from the West Middlesex Water-works.

A gallon gave nearly 0·19 grain of suspended impurity.

A gallon, evaporated to dryness, left 19·8 grains residue.

The 19·8 grains were composed of—

Carbonate of lime	15·5 grains
Sulphate of lime and common salt	4·3 „
	19·8 „

Chelsea Water-works, taken from the River opposite.

A gallon gave of suspended impurity 0·66 grain.

A gallon, evaporated to dryness, left 19·4 grains of residue.

The 19·4 grains gave—

Carbonate of lime	16·5 grains
Sulphate of lime and common salt	2·9 „
	19·4 „

Chelsea Water-works Water as it came in, and not allowed to settle.

A gallon gave nearly 0·1 grain of suspended impurity.

A gallon yielded, by evaporation to dryness, 19·8 grains residue.

The 19·8 grains were composed of—

Carbonate of lime	16·4 grains
Sulphate of lime and common salt	3·4 „
	19·8 „

Thames Water, Windsor, taken above the Town.

A gallon gave, by evaporation to dryness, 14·80 grains residue.

The 14·80 grains consisted of—

Carbonate of lime	10·26 grains
Sulphate of lime	3·04 „
Common salt	1·50 „
	14·80 „

Mr. Phillips. It is to be observed that the water taken above Windsor contains less saline matter than that taken from any other place lower down the river.

5. Will you state the general characters of the specimens you analyzed, as applicable, so far as might be determinable by analysis, to domestic purposes?—Supposing always that the water, either by subsidence or filtration, is rendered clear before use, I cannot see that there is any purpose whatever to which Thames water is not applicable. Like other water which receives large quantities of animal and vegetable matter in a state of decomposition, it will of course undergo the putrefactive fermentation, but this is quite extraneous to the intimate nature of the water.

Thames water is scarcely to be reckoned a *hard water*, and as the principal substance which renders it hard is *bi-carbonate*, and not *sulphate of lime*, the former is decomposed, and the water rendered softer by boiling; whereas, if *sulphate of lime* were present in large quantity, it would, within certain limits, become harder by boiling. I therefore consider Thames water as applicable to all purposes, whether manufacturing or domestic, though it must be admitted that, like river water in general, it is flat when it is drank.

6. What was the analysis of the Thames water which you were requested to make for the Lambeth Water Company?—The Thames water which I analyzed for the Lambeth Water Company was taken from Thames Ditton. This water was free from smell or taste, and although not perfectly clear, yet by standing it becomes as bright as if it had been filtered.

A gallon gave, by evaporation to dryness,—

Carbonate of lime	.	.	.	12.34 grains
Sulphate of lime	.	.	.	1.82 „
Carbonate of magnesia	.	.	.	1.84 „
Sulphate of magnesia	.	.	.	0.90 „
Chloride of sodium, with a trace of }				
chloride of potassium	.		}	1.80 „
Silica	.	.	.	1.10 „
Organic matter, with a very minute }				
trace of oxide of iron	.		}	0.65 „
				20.45 „

I also analyzed, but not minutely, the water supplied by the Lambeth Company, taken from the main near the Obelisk, St. George's Circus. A gallon gave 22 grains of residue by evaporation, which appeared to contain a little more organic matter than that of the water from Thames Ditton, and on standing it did not so readily become clear.

7. What was your opinion of the water as respects salubrity?—I consider the water from Thames Ditton, and also from Windsor, as perfectly salubrious, and though Thames water when less clear than these is not so agreeable to drink, I do not think that any of the specimens which I have examined can be considered as positively insalubrious.

9. Have you not had occasion to analyze any hard drainage waters or shallow spring waters?—Several years since I examined, but did

not analyze, the water of a constantly running spring at the Military Mr. Phillips. College near Bagshot; it was remarkably pure.

I have likewise examined the spring water at Ascot; it is remarkably pure.

One gallon yields, by evaporation, 6·4 grains.

These 6·4 grains consist of—

Carbonate of lime and common salt .	5·0 grains
Silica	1·0 „
Magnesia, a minute trace of oxide of } iron, and vegetable matter .	0·4 „
	6·4 „

I have also analyzed the water at Claremont. I have not been able to lay my hand on the results at present. To the best of my recollection it greatly resembled that from Ascot, and at any rate it was remarkably pure.

12. Have you had any occasion to examine any specimens of Artesian-well water?—Some years since I made a general examination of them, but they have since been more minutely analyzed by several persons.

13. Besides the Thames water, have you analyzed any of the streams contributing to the Thames?—*I have analyzed the water of the Colne.*

A gallon gave 21·3 grains of residue by evaporation.

These 21·3 grains consisted of—

Carbonate of lime	18·1 grains
Sulphate of lime and common salt .	3·2 „
	21·3 „

The suspended impurity was 0·1 of a grain in a gallon.

I may here repeat the statement which I have already made with respect to Thames water, that the water of the Colne contained also traces of magnesia, silica, oxide of iron, and organic matter.

Water from the Otterpool, or Main Spring, just above Bushy Park.

A gallon gave by evaporation 21·3 grains.

These 21·3 grains contained—

Carbonate of lime	18·8 grains
Sulphate of lime and common salt .	2·5 „
	21·3 „

It also contained traces of the same substances as above mentioned with respect to the water of the Colne.

The suspended impurity was nearly 0·14 of a grain in a gallon.

Water from the Main Stream of the Valley, or the Spring which supplies the Colne.

One gallon gave by evaporation 21·8 grains.

These 21·8 grains were composed of—

Carbonate of lime	19·3 grains
Sulphate of lime and common salt .	2·5 „
	21·8 „

Mr. Phillips. The mechanical impurity amounted to 0·2 of a grain in a gallon.
 It also contained traces of the substances found in the above described specimens.

I have also analyzed the spring water at Claremont, which rises in a pond at about two miles distance from the house.

A gallon of this gave by evaporation 5·7 grains.

These 5·7 grains consisted of—

Common salt	2·7 grains
Sulphate of lime, with traces of silica, oxide of iron, and organic matter	3·0 „
	5·7 „

It may be proper to add that on account of the purity of the water of Bagshot, Ascot, and Claremont, it was found that the lead pipes which conveyed and the cisterns which contained it were most injuriously acted upon by it.

GEOLOGICAL.

MEMORANDUM OF ROBERT AUSTEN, Esq., Chilworth Manor, Guildford, Surrey.

Mr. Austen. MY LORDS AND GENTLEMEN,

YOU require me to furnish you with some notes on the area of the Bagshot sands, as a source of water supply for London. The points to which you more particularly call my attention in the memorandum with which you furnished me yesterday are these—

§ 1. The probable limits of the gathering ground.

§ 2. The points where the water specimens had best be taken.

To these, therefore, I shall confine myself, in the present instance—

§ 1. The Bagshot sands, as a continuous series of beds, extend from Esher to Strathfieldsaye, east and west, about 30 miles. Their width is variable; they occur north of Virginia Water, and their most southern point is on the summit of the high ground above Farnham. If we estimate them to have a mean breadth of 10 miles, they will cover an area of 300 square miles.

The composition of the beds of this series is remarkably uniform.

a. The upper portion consists of pure silicious sands. This division attains its greatest thickness about the north and east portion of the mass, as at Bagshot Heath, Chobham Ridges, Romping Downs, Finchhampstead Ridges, Hartford Bridge Flats. These sands are from 200 to 300 feet in thickness.

b. Beneath these sands is a retentive stratum of marsh and clay, varying from 5 to 15 or 20 feet in thickness.

c. The lowest portion consists of white and pale yellow sands, purely silicious for the most part, the subordinate argillaceous strata being at the eastern portion of the map.

§ 2. Over the areas of the upper and lower sands much rain-water is absorbed as fast as it falls. That of the upper sands is thrown out, and collected over the surface of the retentive stratum, No. 2. At the junction of the two all the streams and streamlets take their rise, and

this same retentive stratum, where denuded, supports the water courses Mr. Austen. and ponds of the district.

Water also collects on the surface of the upper and lower sands, where argillaceous beds occur; some portion of these areas might, therefore, be made available; at present the greater portion sinks away, till it meets with the next water level, held up by the London clay, on which the whole of the Bagshot series rests.

As the arrangement of the strata in the east, south, and west is basin-shaped, few or no springs are thrown out along the edge of the mass on these sides, so that the accumulation of water is inwards.

The ridges of Esher and Claremont may almost be considered as outlying masses, cut off by the course of the river Mole. The drainage from this portion is thrown out partly in Ditton Marsh, where specimens of the water can be obtained.

On the west end of the mass the Blackwater cuts off a large portion, and carries away the drainage to the west and north.

From Ash to East Hampstead a range of high hills belonging to the upper sands (Ash Common, Romping Downs, Chobham Ridges, East-hampstead Plain), form a parting ridge between the drainage of the Blackwater and that which flows towards the river Wey. Being,

My Lords and Gentlemen,

Yours very obediently,

ROBERT W. AUSTEN.

To the Commissioners of the General Board of Health.

MY LORDS AND GENTLEMEN,

SINCE I communicated to your Board a memorandum respecting the situation and extent of an area of uncultivated land, consisting of clean silicious sands, and calculated to afford surface-water in a state of purity, I have again gone over the area with Professor Ramsay, of the Geological Survey, for the purpose of pointing out to him that the tract in question presented very many conditions of first importance towards the collecting and storing of water in large quantities.

As Professor Ramsay was personally unacquainted with the district, I was anxious that the description I had given to your Board should be confirmed by some independent and competent authority; and I, therefore requested, and had the advantage of, Mr. Prestwich's company, whose geological inquiries have given him a most thorough acquaintance with the mineral structure of the Bagshot area.

This survey has tended to confirm very strongly my first impression, that the area I have laid down in the accompanying sheet of the Ordnance survey, and which is the same as that which I pointed out on the first day on which I attended your Board, is one which is most deserving of your attention.

It will be seen that the water supply is proposed to be taken exclusively from the elevated ground north of Farnham, from the Chobham Ridges, from the Romping Downs, as well as from the high land extending from Bagshot Heath to the Fox-hills, near Chertsey, the whole of which districts belong to that division of the Bagshot sands, which constitutes their upper portion, and whose composition was explained in the memorandum above alluded to.

Mr. Austen.

The peculiar advantages which this area presents consist, first, in the circumstance that great quantities of water can be collected at once from streams of considerable volume, and before they have been rendered impure by the influx of the sewage of inhabited districts. Secondly, that the surface-drainage may be accelerated, whereby loss by evaporation will be diminished; and lastly, that it affords considerable facilities for its collection.

Reservoirs of any depth, and which might have several square miles of surface, may be formed over a stratum of retentive ground about a mile and a-half east of Chobham Place. In like manner great stores of water might be secured by the adaptation of such depressions as those at Coldingly Moor, Haythorne Moor, and one other further north, to receive the surface-water of the east of the Chobham Ridge.

Fleet Pond, which serves as the natural reservoir of the soakage from the high tract of Farnham Beacon, may be enlarged to a great extent.

I more particularly attended to the possibility of increasing the areas formed for collecting the waters of the Ash and Romping Downs, for the purposes of the high level of the Basingstoke Canal, and I pointed out that in every instance such areas might be enlarged; to this I conceive there could not arise any objections on the part of the trustees of the said navigation, inasmuch as their supply would thereby be rendered more abundant and certain.

The elevation of the whole of the district I have indicated is a most important physical feature, with reference to the supply of London.

In suggesting to your Board that the district is one most deserving of your consideration, I would point out that the amount of supply will, in a great measure, depend on a well-considered plan of surface-drainage, by means of earthen pipes, the success of which will depend on the application of physical consideration of several kinds.

The selection of specimens of water should be made only under the inspection of some person thoroughly conversant with the geological structure and mineral composition of the district, and any less accurate course would be highly dangerous, at a time when there are so many conflicting opinions and interests as to the future source of the water supply of London.

Before calling for more accurate data, as to the sufficiency of the supply which may be expected, I would recommend that the quality be ascertained, distinguishing, in every case, between surface-drainage and water of percolation. Being,

Yours very obediently,

London, March 1, 1850.

ROBERT W. AUSTEN.

LETTER from A. C. RAMSAY, Esq.

Mr. Ramsay.

*Geological Survey of Great Britain.
Merchlyn, Conway, North Wales,
May 25, 1850.*

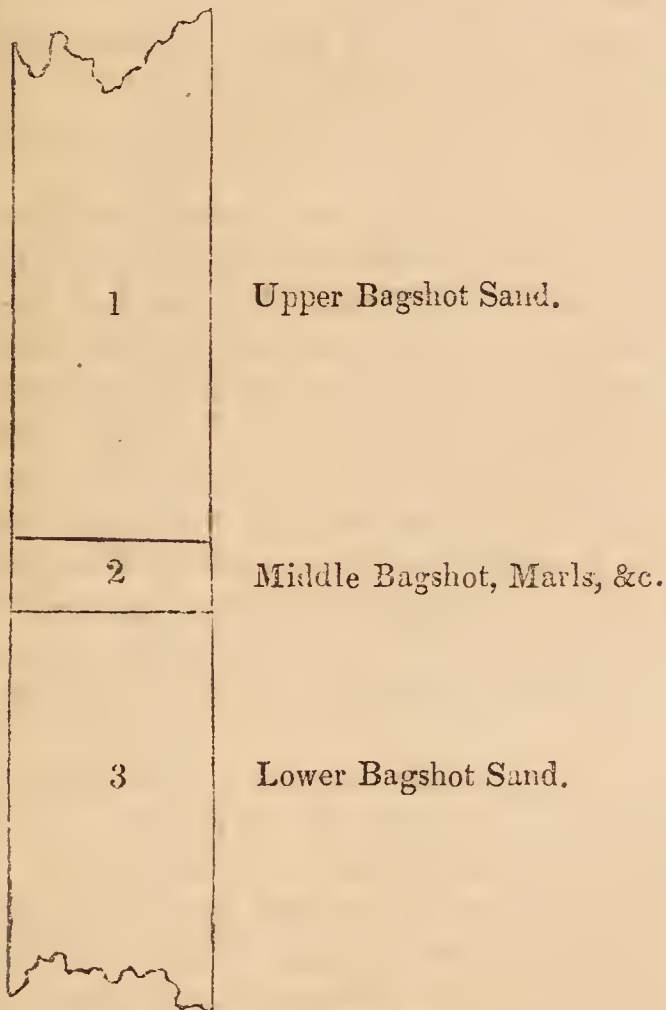
MY LORDS AND GENTLEMEN,

IN accordance with an application made to Sir Henry de la Beche last February, I proceeded with Mr. Austen to examine that district in Surrey occupied by the formation known to geologists as the Bagshot Sand, with the view of ascertaining the nature of its geological

characteristics, that in this respect you might be the better enabled to form an opinion as to the applicability of part of the area to furnish a supply of water for the use of the metropolis. Mr. Ramsay.

The length of this district is about 30 miles, and the average width of the larger portion about 12.

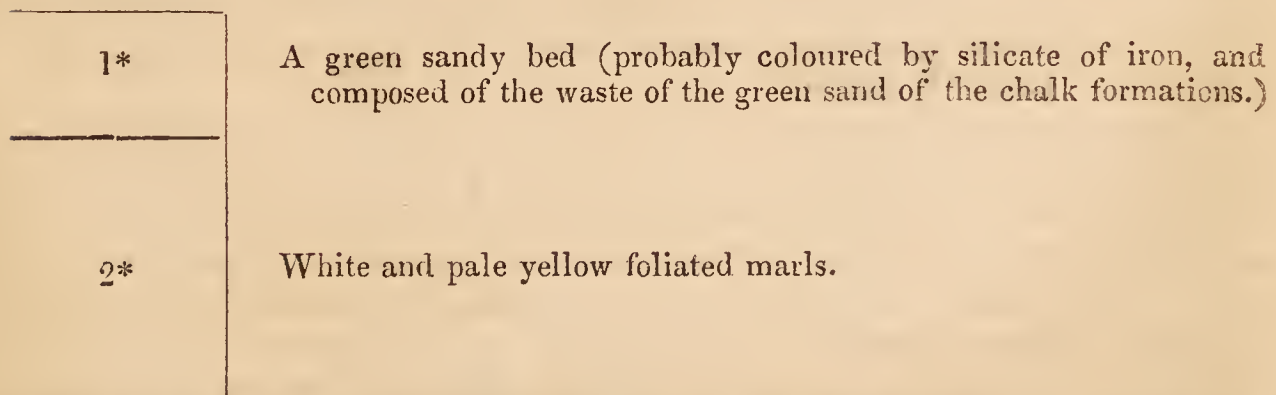
Its geological subdivisions are,—



A general idea of the manner in which these beds appear on the surface, will be obtained from the appended horizontal section. Their mineral structure is as follows:—

1st. Upper Bagshot Sand—generally a fine light brown sand, somewhat of the colour of pale brown sugar. It appears (as far as can be determined without absolute analyses) to be nearly pure silicious sand, slightly coloured by an oxide of iron.

2nd. The Middle Bagshot beds, from 20 to 30 feet thick, generally composed of—



3rd. Lower Bagshot Sand—mostly silicious sand, of somewhat similar texture to the Upper Bagshots, and darker in colour.

The Middle Bagshots (2), form an irregular and generally narrow band, resting on and contained within a wide area composed of the

Mr. Ramsay. lower sands. The Upper Bagshot Sand, for the most part, occupies the higher grounds within this band, such as Romping Downs, Chobham Ridges, &c., &c. For these and other physical reasons (such as its waste character, &c.), it would probably be for the most part desirable to employ the area contained within the circumference of the Middle Bagshot marls for the collection of water from the surface.

The whole series is often obscured by a superficial covering of loose sand and gravel, varying in thickness from a few inches to 20 or 30 feet, and this in the higher waste grounds is generally overgrown by a thin covering of heath. As far as I am aware no deep extensive mosses exist, or are common in the district.

Owing to the incoherent texture of the Upper and Lower Bagshot Sands, they are easily percolated by water, so that a large proportion of the rain that falls on the district must, necessarily in the first instance, be absorbed. This circumstance is rendered apparent by the fact that the smaller valleys branching out on either side of Chobham Ridges were, when visited by me, destitute of brooks. The water so absorbed is, however, checked in its downward course by the Bagshot marls (2), and when the disposition of the strata is favorable, it is thrown out to the surface at the junction of these marls with the Upper Sands (1), forming a series of springs round the retentive marly outcrop, and frequently collecting in pools of considerable area when partially intermingled with the surface drainage. (See Appendix, diagram No. 2).

Notwithstanding the apparently purely silicious nature of the Upper Bagshot Sand, experience nevertheless shows, that in wells sunk in it, the water attains a considerable degree of hardness.

This fact was stated to me by Mr. Prestwich, whose knowledge of the geological structure of the country is exceedingly minute; and the circumstance was further corroborated by the practical experience of the landlord of the "Tumble-Down-Dick," who was in the habit of sending his horses to water at the neighbouring pool, in consequence of their being griped by his well water. This hardness must arise from the diffusion of carbonate of lime throughout the sand in quantity, which though too minute to be detected in ordinary specimens, is yet sufficient to affect the rain water percolating a sufficient area and depth. As might, under these circumstances, be expected, the springs that break out at the junction of the Upper (1) and Middle Bagshot beds (2) are also somewhat hard, and sometimes possess a chalybeate taste, the latter quality being probably induced by the percolation of water through the green sand which forms the upper bed of the Middle Bagshots. (See 1*, above.)

Nevertheless the water of all the pools visited by me (viz. Mitchet-pool, Wharf-pond, Fleet-pond, Flutters-hill-pond, Gracious-pond, &c.) seems (as far as could be judged on the spot without the means of absolute testing) to be of soft quality, and it would therefore appear that in the main the pools are principally replenished by surface drainage. They were also invariably sweet and pleasant to the taste, altogether different from any of the ordinary London waters with which I am acquainted, and reminding me in this respect of the pure waters of North Wales.

The surface sand and gravel which covers the larger part of this district is, in a great measure, composed of the detrital waste of the

Nº 1.



- 0 Superficial Sand and Gravel.
- 1 Upper Bagshot Sand.
- 2 Middle Bagshot beds (Marls &c.)
- 3 Lower Bagshot Sand.
- 4 London Clay.

This is not an actual Section over any given District, but simply a diagram illustrative of the general disposition of the beds.

Nº 2.



Point where Springs rise at the junction of the upper Bagshot Sands, and middle Bagshots (Marls.)

Pool

underlying beds of Bagshot sand; and, from its apparent quality, the *surface* drainage might be expected to be generally free from calcareous impurities, any little lime that may once have been intermingled with the surface detritus, having probably long since been carried off in solution. Mr. Ramsay.

The summit level of the canal at Wharf-pond (which is fed by the overflow of the canal), should afford a perfect test of the quality of the surface drainage of the district, the canal being there necessarily exclusively supplied with water from that source. It appeared to me that it did not differ in quality from the water of the other pools to which I have already alluded.

The entire area of the Upper Bagshot Sand is probably somewhat between 80 and 100 square miles. The average quantity of water now carried off in streams from this area, and any portion of the Lower Bagshot Sands that may be considered available; also the proportion of this district that may be available for the increased collection of water by surface drainage, together with the facilities for increasing the areas and depth of pools, &c., where it may be collected, would be easily ascertainable in the event of the execution of accurate topographical and other surveys of the district. These being purely engineering points, the nature of my investigations, and my necessarily limited stay on the ground, did not permit me to form any precise opinion regarding them.

I have the honor to be,
My Lords and Gentlemen,
Your most obedient servant,
ANDREW C. RAMSAY.

*To the General Board of Health,
Gwydyr House, Whitehall.*

MISCELLANEOUS.

J. M. Paine, Esq., of Farnham, examined.

What is the population of the town of Farnham?—The town has a population of about 3,500; the parish a population of 7,000. Mr. Paine.

How many houses are there in the town?—740.

How many houses do the Water Company supply?—116; but the poor people have the water for nothing, in any quantity they please, from their neighbours.

What are the terms of supply?—I will put in the following table:—

FARNHAM WATER COMPANY.
Terms for supplying the Inhabitants of Farnham with soft Water.
For ordinary Domestic Purposes.

				Per Quarter.	
				s.	d.
Houses of the first class	.	.	.	5	0
„ second ditto	.	.	.	4	0
„ third ditto	.	.	.	3	0
„ fourth ditto	.	.	.	2	0

And where water is required for the purpose of domestic brewing or

Mr. Paine. washing, or for a water-closet, an additional fourth part of the first charge, according to the class of the house, for each purpose.

Public brewers 25s. per annum, and for every additional house for the sale of beer supplied by them 15s. more, beyond the ordinary class charges for domestic purposes and washing.

Licensed victuallers 25s. per annum for brewing, beyond the class charges for domestic uses, and washing and water-closets; and 20s. for yard purposes—first class, 7s. second class, and 5s. third class.

Maltsters 25s. per annum for each malt-house.

Washing-women 20s. per annum.

All water-rents to be payable quarterly, and in advance, and each consumer to sign an undertaking to abide by the terms of the Company.

WM. MASON,

15th August, 1836.

Secretary and Acting Manager.

At this rate of charge the Company now receives 5 per cent. dividend per annum on the total outlay.

Farnham is situated on the Chalk, is it not?—The greater part of the town of Farnham is below the “Chalk,” it being situated upon a bed of gravel lying upon the upper part of the “Lower Green Sand.” The parish of Farnham comprises the whole of the chalk formation, together with part of the Lower Green Sand on the south, and the London clay on the north.

Was it not the original source of the supply of water for the town?—The town was always abundantly supplied with good hard spring-water, obtained from wells. This supply, of course, still remains.

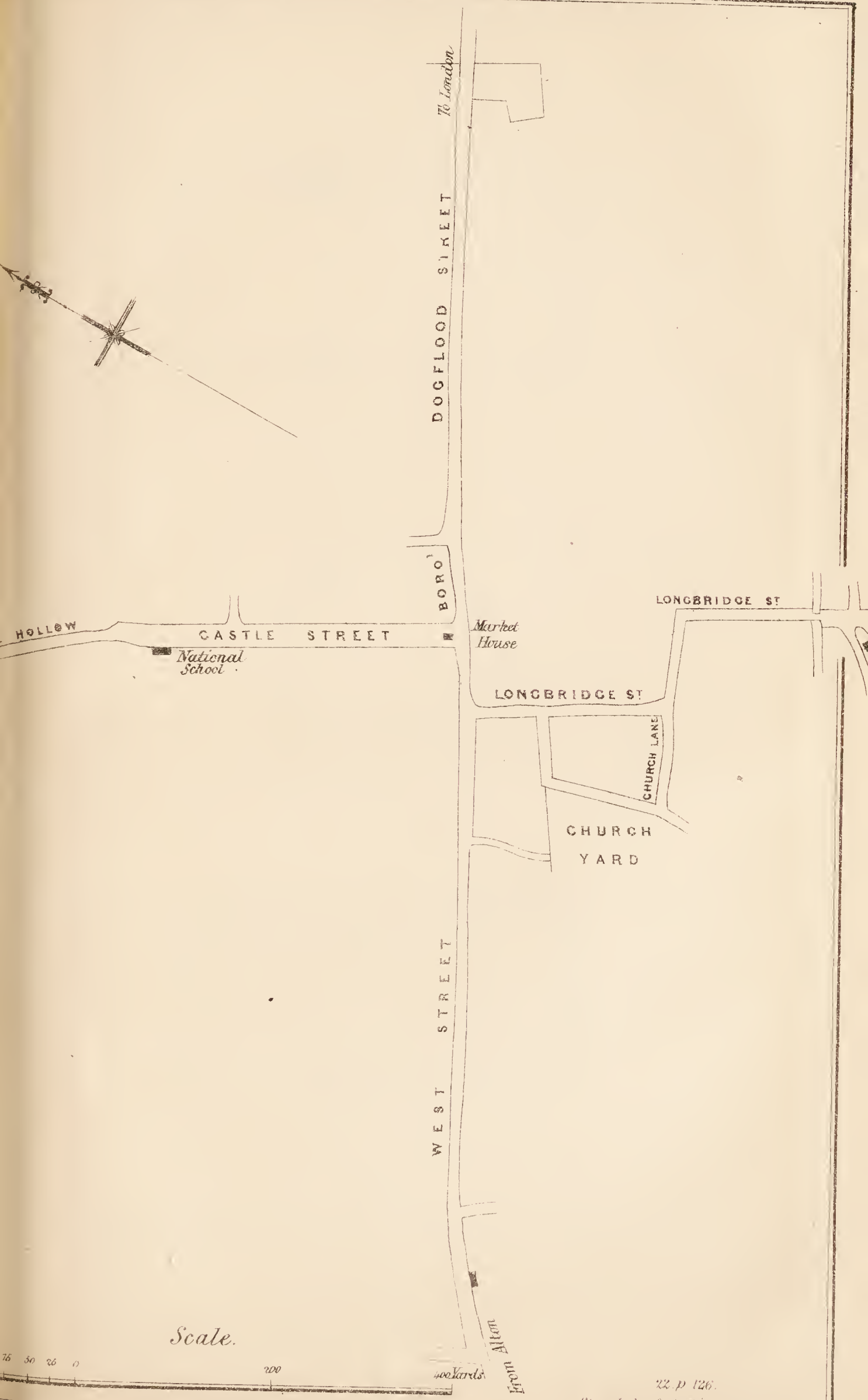
Will you describe the circumstances which led to the change of the source of supply?—Soon after the introduction of gas into the town, about 15 years since, my father and one or two other influential inhabitants thought it would also answer well to bring the soft water from the waste commons on the north of Farnham into the town, which would afford a constant supply of pure soft water to the top of every house. The project was successfully carried into execution. This water had always been used in comparatively small quantities for washing purposes from time immemorial, there being a small reservoir in the town which received the superfluity of water from the Castle, the residence of the Bishop of Winchester. From this reservoir the inhabitants were accustomed to fetch it in water-barrels. The superior properties of the water for washing purposes have therefore long been appreciated. The present supply is abundant and continuous, and might, if required, be increased to double the quantity at the expense of a few pounds.

Will you describe the nature of the ground which you have taken as a gathering ground?—A grant of 20 acres was made by the Bishop of Winchester, as lord of the manor, and a small portion of that ground, some two or three acres, were drained.

What was the condition of that ground before it was drained?—It was a peaty bog, resting on a gravelly, sandy subsoil, that again resting on a substratum of London clay. It was such a boggy or marshy surface as sportsmen would understand if it were called “snipe-shooting ground.”

What sort of drains did you put in?—The ordinary earthen pipe drains. The sand is of a very loose character, so that it has frequently choked up the drains, making it necessary that two or three times they should





Scale.

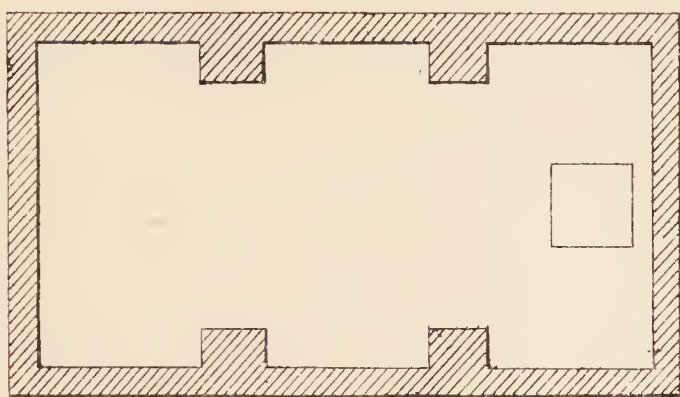
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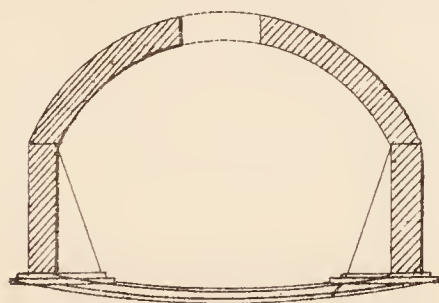
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Standridge & Co Litho 36, Old Jewry



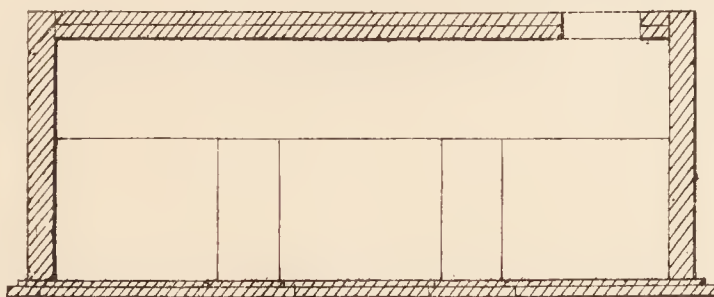
GROUND PLAN.

Ground Line



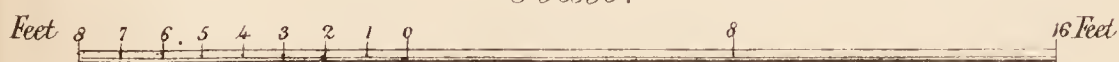
TRANSVERSE SECTION.

Ground Line



LONGITUDINAL SECTION.

Scale.



be taken up. Subsequently, however, the main drains were formed of iron pipes, the auxiliary drains still remaining of ordinary earthen pipes. If the work had to be done again, superior earthen pipes should be used, as a better kind is required to resist the pressure. Some of the pipes had become soft as clay, having been badly burnt.

What is the size of your branch-drains?—The branch-drains are four inches, and the trunk eight.

What is the fall?—From the top of the common to the market-house, in the centre of the town, it is 280 feet. The water runs from this gathering-ground to a small reservoir on the common. This reservoir consists of a small tank into which the water flows, and from thence it is conveyed by iron pipes into a large tank near the Castle gate. The tank contains about 1,000 hogsheads, or 60,000 gallons.

Then those houses which require it are large houses?—Yes; most of the cottagers have the water for nothing.

Are the wells still used in the town?—Yes, but the water is never used for brewing or household purposes. I have never heard, however, of new wells being sunk since the waterworks were established.

Farnham lying on the chalk, and the water being very hard, did not the people find the difference between it and the soft water so important that they sent carts as far as a mile to fetch the latter?—Yes; and the superfluous water from the Castle has been used by them from time immemorial.

Are you aware that the tea at the Bishop's Castle at Farnham has been always admitted to be of very excellent quality?—Yes, the green tea has always been considered very excellent; and since the soft water has been introduced into Farnham, a great difference has been found in the quality, and also that a less quantity of tea has been required.

What would you describe as the effect?—Three cups may be produced with soft water of equal strength to two with hard water, using of course the same quantity of tea.

You think that a fair popular statement?—Yes; but there will be the difference in a superior flavour in addition, which is very distinguishable with soft water.

Do you know anything of its use in cooking?—Nothing particular; but I know it is preferable for cooking vegetables. I only know that now hard water is never used except by those who prefer it for drinking. It may be a little colder and a little more sparkling from the carbonic acid gas.

Do you not think that the coldness of the soft water might be increased by extra care in the delivery of it?—My impression is that this water is remarkably cold for a supply of such a description. I never taste water so cold elsewhere. This is owing to our pipes running low under ground, and to it being received in a reservoir: thus it does not imbibe any warmth from the atmosphere.

Was not this water originally collected from a spot which might have been described as "snipe-shooting ground?"—It was.

What was the effect of drainage on the surface?—It completely drained it.

Taken from the surface originally, what was its appearance?—Very similar to what I have observed the Blackwater River to have: it had a brownish appearance; but now, when it is obtained from under the surface, it comes out quite clear; and that induces me to believe that

Mr. Paine.

water obtained from under drainage would get rid of all vegetable impurity and come up perfectly clear.

The Farnham water was first noticed, was it not, by Professor Way from its pureness?—Yes. He was performing some experiments, for which he wanted distilled water. I directed his attention to our soft water, which surprised him by its purity. He tried it, and found it to be nearly as pure as distilled water, and it answered the purpose for which he required it.

Then this pipe-drainage has not only collected the water in greater quantity and brought it to this state of purity, having no taste or colour left, but it has also altered the surface of the ground, too?—Yes; and it has rendered the ground fit for cultivation which was previously unsuited for that purpose. Some is in grass, and other portions are used as garden-ground.

Have you observed anything to induce you to believe that the same results might not be obtainable from an extension of subsoil or agricultural drainage over the whole of this district?—No; we have specimens of water taken a mile apart, and precisely the same in character.

At what points was this water taken?—From three points; one from which the Bishop's supply is taken, and from two other places on either side, each about half a mile from the other. All the waters were equally pure.

For how many houses does this drainage of two acres give you a supply?—For 116 houses, night and day; and they do not use half the supply that is obtained; and the addition of a drain from one point might, for an outlay of 10*l.*, give double the quantity we now have, if necessary.

Have you met with any instances of the soft water passing over chalk becoming hard in the course of a short distance?—Yes; when it passes through about a quarter of a mile of chalk it becomes intensely hard. We have an example where the soft water runs into a swallow hole into the chalk, and it rises again, about a quarter of a mile eastward, in a pond, where it comes out intensely hard. That is an instance of the hardest water we have.

Do you think that the whole surface of this district would give, acre for acre, a similar quantity to this?—No; if I were to drain the whole of the hill I would only lay pipes round the sides of the hill, and thus get the natural drainage. The water would, in fact, be naturally drained to those spots, which would be indicated by the marshy appearance of the surface.

Has there been any experience as to the effects of the water in respect to the furring of kettles?—I have inquired of the plumbers, &c., in the town, whose business it is to clean boilers, kettles, &c., and they all agree that our hard water furs very much, while the soft water from the commons scarcely leaves any fur at all. I may mention as an illustration, one of them told me that my own boiler at my late residence, which is supplied with hard pump water, requires cleansing once in three months; while that of the Bishop of Winchester, which is supplied with the "commons" soft water, does not require cleansing more than once in 13 or 14 years. In my present residence I use the soft water.

What are the results as regards brewing?—My own experience, as well as of the brewers and inhabitants generally, is decidedly in favour of the soft rather than of the hard water of the town.

Has there been any experience also as to the effects on cattle of hard and soft water?—All farmers prefer soft water for their cattle. The people who live upon our commons state, that when their horses drink our chalk water, or the water from the River Wey, it disagrees with them, and often causes what is termed the “fret.”

Then the supply to the Bishop's Palace is constant?—Yes; but it has no connexion with the town supply. It is derived from another “tapping” of the hill.

Is the water conveyed there through lead pipes?—Yes.

Your supply also is through many leaden pipes in the town?—The mains are of iron, but the pipes which convey the water into the houses are of lead.

Have you heard of any casualties from the effect of the soft water upon these leaden pipes?—I am not aware of any having happened; the supply is constant, and consequently there is no need of cisterns.

How long has the supply been in existence at the Bishop's Palace?—I should say, 200 years, or perhaps more.

How long has your own supply been in operation?—Since 1837.

You are, I believe, a native of Farnham, and acquainted as an agriculturist with all the country around?—Yes.

From how many miles of surface, as far as you have observed, can a similar supply to that of Farnham be obtained?—I should say, from a district of 15 miles in length, and varying from 3 to 6 miles in breadth, lying between Farnham and Wokingham.

Is that the white sand district?—It is commonly known as the Bagshot sands; but I must add, that when there is a great depth of sand, water is not obtainable by drainage, and it is useless to drain unless you have an impermeable sub-stratum for the drains to rest on.

Is there a great quantity thrown off the surface?—Yes, I have seen quite a river flowing from it after a thunder storm from those parts of the commons which have a sub-stratum of clay at a moderate depth.

And was that such water as would admit of filtration?—Yes, and it would thus be deprived of its vegetable peaty quality.

Might it be cleared of the peat?—If I wished to have water from off this district I should break up the heath and allow the water to go under ground and catch the water in drains, I believe it would then come out perfectly clear.

It has been stated to us by our agricultural surveyor (*Mr. Donaldson*), that this peat is so thin that it might be peeled off very easily?—Yes, it is very thin at those parts whence we obtain our supply, but between Aldersholt and Cove the Eelmore Bogs have a thickness of from 8 to 10 feet deep, but the surface of it might easily be stripped, and the peat might be sold and pay the expense of the process. From these low grounds I suspect that a large supply of water might be gathered.

Then the surface might be cleared at very little expense?—Yes, for a very few pounds indeed: about 2*l.* an acre on an average; but when the peat is deep, the expense would be more. Even then the peat would pay the expense.

Do you know whether iron is found much in the district?—Certainly not in this district, which lies on the north side of Farnham; but on the south-east, on the “Lower Green Sand,” there are many beds of iron-stone.

Mr. Paine.

Have you seen any reason for believing that if the land were drained it would diminish the taint of iron if it should be found expedient to use the red sand wastes as gathering grounds?—I have seen at some six or seven miles south-east of Farnham the water come out pure from the lower green sand, but it comes through a broken-up soil of diluvial grit similar to that on the north side of Farnham, and that has also been reputed soft and useful for domestic purposes.

Have you any notion of the proportionate quantity of rain-fall which might be derived from the lands of the district under consideration?—Within the vicinity of Farnham we have a less quantity of rain than at some seven or eight miles distance. Towards Woking, in showery weather, they have much more rain than we have.

Do you, on the whole, think the estimate an unfair one that one-third the quantity of rain-fall is obtainable by draining?—I think if the subsoil prevents the permeation of the water, more is evaporated. It is impossible to lay down any general rule.

Since you have drained the portion of land for the supply of your town, does less water lie on the surface?—None is to be seen on the surface, as it goes into the drains. A great quantity of water is lost if the drains are not deep enough. If we were to put other drains underneath the present ones, we should catch much more.

Then your own view is, that your works were first rude suggestions, and might now be much improved?—Very much; they cost us 2,040*l.*, and if the work were to be done *de novo*, we might do it for 1,200*l.* and get more water.

With respect to the ground which you describe as having been in its original state a snipe-shooting ground, how much more water do you think has been obtained by drainage than could have been obtained by a discharge of mere surface water, after allowing for surface evaporation?—There is no comparison between the two, as, in the one case, we had only the water which flowed from the immediate surface, whereas, by drainage, we have obtained the water from a much larger extent of ground.

Suppose you took gaugings of the principal outfalls prior to the drainage, and those derived from the district uncultivated and unworked, for water purposes, could you, from your own observation, form any notion of the proportionate difference of that produced from the whole drained surface, compared with land in its undrained condition?—I can judge to a great extent from common observation, as the flow of water is now very much larger from the drained ground than what seemed to flow from the same spot before drainage.

Of course since the draining the water does not lodge any longer on the surface, and as the bog has entirely disappeared, all the bog evaporation must be saved?—Yes; the soil is so porous that if you drain it underneath, so as to allow the water to pass off as it falls through, very little is lost by evaporation, and I believe that kind of soil spreads over a large portion of this district of country.

Then you see nothing to effect the conclusion that by like care being extended over the whole district, some 15 miles long, to from three to six or seven miles wide (thus making some 80 square miles of gathering ground), water of a similar quality to that delivered in Farnham would be obtainable?—I think so; but I should not drain the whole surface of the district, but only those spots where water is found to ooze out at the sides of elevations.

Have you had instances of losing large quantities of water through swallow-holes?—Swallow-holes are not found in this stratum: they are numerous in this neighbourhood *below* the plastic clay which lies immediately above the chalk, and here large streams disappear beneath the surface. But a very considerable quantity of water will disappear sometimes when it passes through a bed of gravel, and will sink to a considerable depth, while it will re-appear again in land at some distance. The best plan would be to drain the outskirts of the London clay, and by that means the whole of the water would be obtained.

If there were any selection to be made, of course, from your experience, you could easily avoid particular beds of a peaty character, or where iron existed, or which might otherwise be objectionable, and only take those portions which would supply pure water?—Yes; the selection might be entirely under one's own control, by allowing no water to be gathered from these undesirable spots.

Then, with these proportions, you think it practicable to preserve the purity of the water, equal to, if not superior, to that now supplied at Farnham?—I think the whole of the hill from which we derive our small supply, would furnish a great quantity of the same kind of water, particularly on the north-west side, which already discharges a copious supply into Fleet Pond and the Basingstoke Canal; and I infer from the similarity of the super and subsoils, the same description of water might be obtained from the whole of the white-sand district in the direction of Wokingham.

Is there the same appearance of vegetation over the whole district?—Yes; and the same geological appearance.

Has not the water in the Basingstoke Canal the same peaty tinge as the water on your Farnham gathering ground, prior to drainage, had?—Yes, very much so.

Have you followed the old system with regard to the distributory apparatus?—We have simply branch service-pipes running into the houses at right angles with the mains.

What is the greatest pressure of your water in the town?—I should imagine that the larger reservoir at the castle gates is about 40 feet higher than the highest house, and the water comes out with great force at the tops of our houses, and we can throw it in a jet some 30 or 40 feet.

Have you had fires lately in the town?—We have had two fires since this supply of water, and they were both extinguished by its means; and though there was a large draught of water from our tanks on the occasion, we were not obliged to shut up the works in order to fill the reservoirs again.

As far as you have observed, the character of the soil in the district you have spoken of is similar to that from which your supply is taken?—Yes; it is a mixture of sand, gravel, and clay, resting on the London clay, and the depth varies very much.

Have you ever found trees in the pipes? Willows have sometimes been found, as you are aware, in the pipes used for agricultural drainage?—Yes.

May not this be prevented by the use of impermeable pipes within the known range of the roots of trees?—Yes. I have been accustomed to lay a bed of stones round my drains at places where they were liable to such accidents.

Mr. Paine. It has been stated that the quantity of water is increased by wood, and that more falls on forest land than on ordinary cultivated ground?—Yes. More falls and less is lost. Mr. Lawes has made some experiments with different kinds of plants, and grasses, and evergreen-trees, the result of which shows that fast-growing plants within a limited period, such as barley, oats, and wheat, evaporate through their leaves a much larger proportion than forest trees, and that evergreens evaporate very little. The law seems to be this, that rapidity of growth is coincident with a large evaporation of water.

Therefore you infer that if land is cultivated for corn land more water is taken from the soil than under heath cultivation or the growth of fir-trees?—Yes.

Would you not be afraid of taking a portion of the water from ground used as garden-ground?—No, not at all, if there is sufficient clay in the soil to absorb the ammonia. I have some clay soil of my own, where I have put a large quantity of guano; but the water flowing from my drains is quite free from ammonia.

Then you would not be afraid of the quality of water obtainable by deep drainage being deteriorated by proper surface manuring?—Not in such soils as the garden-ground on our commons, which has clay in it. It would have no effect in clayey soils, but in gravelly or sandy soils the water would run through, unless there was enough clay in it to arrest the ammonia.

Then all your experience corroborates Professor Way's experiments?—Most decidedly so.

What quantity of land do you farm?—Some 600 or 700 acres. I have a great quantity of hop-grounds, which require large quantities of manure.

There is a very cheap mode of distributing clay with sand over the surface by means of a jet. Have you had any means of considering how far that mode might be made available to form a surface for the discharge of water for drainage purposes?—I have not had the subject before called to my attention; but I cart clay upon my sandy soils.

Have you tried experiments on the effect of the filtration of manures through different soils?—Occasionally.

Have you tried experiments with regard to the detention of manure on the principle proposed by His Royal Highness Prince Albert, by means of filtration through ashes?—Yes, I have tried experiments which were on the same principle, some time since, only my filtrations were downwards, whereas His Royal Highness's proposal was that the liquid should be forced upwards through the ashes. My plan was to pump the liquid upon the ashes; that liquid consisting of the urine of some 300 or 400 sheep and other cattle, collected in tanks prepared for the purpose.

How long have you applied that plan?—That system has been in operation at my place for some three or four years.

Have you found the effect beneficial?—Extremely so.

Then, on the whole, you are satisfied with the result of this experiment?—I am satisfied that this is a capital means of distributing manure on the land, and I have found from experiment that one bushel of charcoal ashes will absorb the astonishing quantity of 9 or 10 gallons of this liquid manure.

What is the effect as regards the smell of the liquid after filtration?—

I have found that it then possesses very little smell at all, although before it was passed through the charcoal dust the odour was so offensive that you could scarcely bear it. All my experience on the subject tends to confirm the conclusions arrived at in the views laid down by Prince Albert.

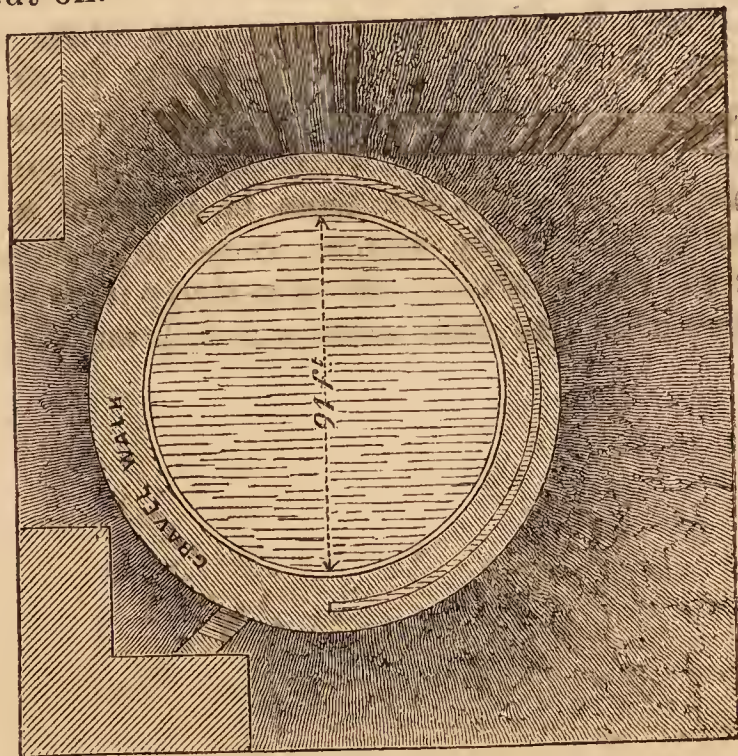
What has been the effect of that kind of manure upon the crops?—I have always applied it in combination with other manures, and therefore I cannot state how much of the benefit I have derived is attributable to this portion of my manures. I esteem it very highly, and continue to make it in very large quantities; being perfectly satisfied that the excellence of my crops is greatly enhanced by this mixture.

LETTER from J. R. COULTHART, Esq.

“SIR, “*Croft House, Ashton-under-Lyne, Jan. 10, 1850.*

“In answer to your inquiries on behalf of the Metropolitan Commissioners, I beg to annex a Table expressly compiled by me for your information, which exhibits the positive quantity of water consumed in 4094 dwelling-houses in 168 hours, in May, 1847; and as the measurements connected with the experiment were taken by Mr. Henry Hibbert, Secretary to the Ashton-under-Lyne Waterworks Company, in expectation of his being sworn and cross-examined as to their accuracy before a Committee of the House of Commons in a matter involving the supply of the town of Manchester with water, great dependence may be placed on the correctness of the statements. Indeed, I am so satisfied of the accuracy of the observations and calculations made, that I doubt much if you will have a return from any other place more deserving of being relied upon. To enable you, however, to test the computations and also the soundness of the principles on which they are based, I subjoin to this letter a drawing of the filtration reservoir, together with the common arithmetical formula used in calculating the number of imperial gallons consumed in the 4094 dwelling-houses, as indicated by the lowering of the water in the circular filtration reservoir of 91 feet diameter, whilst the supply from the large upper reservoir was cut off.

Mr. Coulthart.



Sketch of the Filtration Reservoir, Ashton-under-Lyne.

Mr. Coult-
hart.

“In answer to your inquiry, ‘Whether, from further experience at Ashton-under-Lyne since writing my Report to the Health of Towns Commissioners, I would modify the information therein afforded,’ I would simply say that additional experience has only more deeply confirmed the opinions which I then had as to the importance and economy of a continuous distribution of water for domestic purposes, by which tanks, ball-taps, and turncocks’ wages are wholly saved, without anything existing in the unlimited-supply system to counterbalance these expenses, except, perhaps, that of laying down larger main-pipes. Indeed, daily experience is establishing in this part of England, and the annexed table corroborates the affirmative of the proposition, that a constant and unlimited supply is by far the cheapest method of supplying a given number of dwelling-houses with water; and that the system is not practically attended with that wasteful consumption of the precious fluid which the term ‘unlimited’ would seem to imply. When I wrote in 1843 my Report on the Sanitary Condition of Ashton-under-Lyne, I calculated that an unlimited supply of water involved a daily distribution after the rate of 55 gallons per house, or 10 gallons per head of the population supplied; but subsequent experience has satisfied me that that was an over-estimate of what the public voluntarily use, and that 40 gallons per house, or 7 gallons per head per day, is amply sufficient, on the average, to meet all requirements of a domestic nature.

“In closing this letter I give, as requested, some general information regarding the existing state of the Ashton-under-Lyne Waterworks as compared with their condition when I noticed them in 1843. You will thereby perceive that, though on the average we only charge 8s. 9d. per house per annum, yet the proprietors of the works realize a dividend of $7\frac{1}{2}$ per cent. per annum on the capital expended in their construction (the highest rate of dividend that the Water Act permits to be divided amongst the shareholders, or a much higher could be paid from the profits), and that each of the 25*l.* water-shares are selling at nearly double their original cost. These facts lead me to doubt whether there are any towns in England or elsewhere, with an intermittent supply of water, that surpass Ashton-under-Lyne in the three grand requisites with promoters generally of undertakings of the kind, namely, in the lowness of the cost of the water to the consumers, in the height of the dividend realized by the proprietors, and in the augmented value of the capital originally invested in the undertaking. If my surmises be correct, a good argument might therefrom be deduced in favour of the constant and unlimited supply system, even on pecuniary grounds, which are, after all, the chief obstacles to sanitary improvement.

The comparative statement mentioned is as follows, viz. :—

THE ASHTON-UNDER-LYNE WATERWORKS COMPANY.
(Established in 1835.)

Mr. Coult-
hart.

	In 1843.	In 1850.
	£.	£.
Amount of capital invested	19,288	24,547
Expenses of management, including rates, taxes, and keeping the pipes in order	600	840
Net annual revenue, which was effected in 1845 by a re- duction of the charges	2,400	2,600
Market price of shares (25% paid up)	45	48
Average charge per house per annum	11s. 3d.	8s. 9d.
Entire number of dwelling-houses supplied from both re- servoirs	4,500	5,700
Number of dwelling-houses in the town unsupplied	300	100
Entire quantity of water annually delivered to houses, factories, and railways, in millions of gallons	140	90
Average consumption of water per house per diem, in imperial gallons	39	39
Estimated length of cast-iron and lead pipes, in miles.	11½	17
Number of fire-plugs in the town gratuitously supplied	150	200

“In addition to the fire-plugs the Water Company supply, free of charge, all churches, chapels, schoolhouses, town-halls, and other public places within the borough; also water for all purposes of general utility, such as for the monthly trials of the fire-engines, for the extinction of all accidental fires when they occur, for the watering of the streets in summer, &c. &c.

“I ought also to remark that the 140 millions of gallons, mentioned in the above statement as having been delivered by the Company in 1843, included the supply of water to sundry cotton-factories, for condensing purposes; many of which ceased to be supplied from the Ashton-under-Lyne Waterworks in 1846, a number of the factory-owners and occupiers having in the latter year established separate waterworks for themselves for these purposes.

“I have the honour to be, Sir,

“Your most obedient Servant,

“Henry Austin, Esq.”

“JOHN ROSS COULTHART.

Mr. Coult
hart.

TABLE showing the actual quantity of water consumed in one week in 4094 dwelling-houses in Ashton-under-Lyne, in the county of Lancaster, where a constant and unlimited supply has been in operation for a period of 14 years; distinguishing also the daily and nightly consumption of each house, and of each individual member thereof, as compiled by JOHN ROSS COULTHART, of Croft House, Ashton-under-Lyne, from measurements carefully taken of the depressions observed in a large circular filtration reservoir of 91 feet diameter, by Mr. HENRY HIBBERT, Secretary to the Ashton-under-Lyne Waterworks Company.

DATE.		Hours at which the Measurements were taken.	Distance of Water from top of Reservoir.	Depression of circular Filtration Reservoir of 91 feet diameter, whilst the supply of Water from the upper Reservoir was shut off.	Time.	Diminution of waste Goit during same time.	Total Quantity of Water absolutely delivered to 4094 Dwelling-houses.	Average Quantity consumed in each Dwelling-house.	Average Quantity consumed by each Individual supplied.*
			Ft. In.	Ft. In.	Hours.	Ft. In.	Gallons.	Gallons.	Gallons.
1847.									
March	20 Saturday .	9 a.m.	4 4½ }	3 5	9	1 0	142,773	34·87	6·34
„	„ Ditto .	6 p.m.	7 9½ }						
„	21 Sunday .	9 a.m.	3 4 }	1 9	9	1 0	75,023	18·31	3·33
„	„ Ditto .	6 p.m.	5 1 }						
„	22 Monday .	9 a.m.	3 7 }	2 0	9	1 0	85,186	20·79	3·78
„	„ Ditto .	6 p.m.	5 7 }						
„	23 Tuesday .	9 a.m.	3 7 }	2 2	9	1 0	91,961	22·44	4·08
„	„ Ditto .	6 p.m.	5 9 }						
„	24 Wednesday	9 a.m.	3 7½ }	2 2	9	1 0	91,961	22·44	4·08
„	„ Ditto .	6 p.m.	5 9½ }						
„	25 Thursday .	9 a.m.	3 5 }	2 2	9	1 0	91,961	22·44	4·08
„	„ Ditto .	6 p.m.	5 7 }						
„	26 Friday .	9 a.m.	3 5 }	2 7	9	1 0	108,898	26·59	4·83
„	„ Ditto .	6 p.m.	6 0 }						
„	26 Friday .	6 p.m.	6 5 }	1 9	15	1 0	75,023	18·31	3·33
„	27 Saturday .	9 a.m.	8 2 }						
„	„ Ditto .	6 p.m.	4 6 }	1 8	15	1 0	71,626	17·49	3·18
„	28 Sunday .	9 a.m.	6 2 }						
„	„ Ditto .	6 p.m.	4 2½ }	1 4½	15	1 0	59,779	14·63	2·66
„	29 Monday .	9 a.m.	5 7 }						
„	„ Ditto .	6 p.m.	4 1½ }	1 3	15	1 0	54,698	13·31	2·42
„	30 Tuesday .	9 a.m.	5 4½ }						
„	„ Ditto .	6 p.m.	4 1½ }	1 3½	15	1 0	56,392	13·75	2·50
„	31 Wednesday	9 a.m.	5 5 }						
„	„ Ditto .	6 p.m.	4 0 }	1 4	15	1 0	58,086	14·30	2·60
April	1 Thursday .	9 a.m.	5 4 }						
„	„ Ditto .	6 p.m.	4 8 }	1 3	15	1 0	54,698	13·31	2·42
„	2 Friday .	9 a.m.	5 11 }						
Total per week . .				26 2	158	14 0	1118,065	272·98	49·63
Average per diem .				3 86 7	24	2 0	159,723	38·99	7·09

* The population supplied with water is taken at 22,517, being after the ratio of 5½ persons to each house, which was the average proportion given for Ashton-under-Lyne by the census returns, page 41.

Mr. Coult-
hart.

	91 feet, being the diameter of Reservoir.	
	91	
	91	
	819	
	8281	
	7854 number for finding the area of the circle.	
	33124	
	41405	
	66248	
	57967	
	6503·8974 cubic feet in 1 foot of reservoir.	
	26·2 aggregate depression of reservoir.	
	1083	
	39018	
	13006	
	170161 cubic feet of water in 26'·2" of reservoir.	
	6½ number of gallons in a cubic foot of water.	
	42540	
	1020966	
	1063506 number of gallons in 26'·2" of reservoir.	
	54411 number of gallons from waste goit.	
Houses		
4094)	1117917 (272·82 gallons per house per week.	
	8188	
	29911	Again :
	28658	Population 22517) 1117917 (49·64 gallons per head per week.
		90068
	12537	217237
	8188	202653
	3349·0	14584·0
	3239·2	13510·2
	109·80	1073·80
	81·88	900·68
	27·92	173·12

243	length of goit inside.
254·6	,, outside.
2) 497·6	
248·9	average length.
2·6	width of goit.
124·4½	
497·6	
621·10½	cubic feet of water.
2	emptied twice in 24 hours.
1243·9	
6½	gallons in a cubic foot.
310½	
7462½	
7773	total per day from goit.
7	days in a week.
54411	total gallons per week.

* * There is a trifling difference in the entire quantity of water delivered when computed in the aggregate as is done here, which arises from the remainders in the 14 similar calculations in the table, and the rejection of the above, or rather preceding, decimal of ·8974.

Mr. Lindley.

Wm. Lindley, Esq., C.E., examined.

1. What provision is made with the new system of works which you have laid down for the prevention of fires?—The mains are large, from 6 to 20 inches diameter, constantly charged at high pressure, being supplied from the one extremity by two Cornish engines, and at the other level from a high summit reservoir, kept constantly filled. Throughout the whole length of the pipeage are placed, at intervals of 40 yards, fire-plugs of three inches diameter in the clear.

2. How soon can a jet be applied?—In two minutes. The men who get paid by old custom for the use of their engines will come, although they are not wanted, but the power of eight engines may be anywhere applied as quickly as the hose can be screwed on, and introduced *inside* the house where the fire is.

3. Have there been fires in buildings in Hamburgh in the portion of the town rebuilt?—Yes, repeatedly. They have all, however, been put out at once. If they had had to wait the usual time for engines and water, say 20 minutes or half an hour, these might all have led to extensive conflagrations.

4. What has been the effect on insurance?—The effect of the rapid extinction of fires has brought to light to the citizens of Hamburgh the fact that the greater proportion of their fires are the work of incendiaries, for the sake of the insurance-money. A person is absent; smoke is seen to exude; the alarm of fire is given, and the door is forced open, the jet applied, and the fire extinguished immediately. Case after case has occurred where, upon the fire being extinguished, the arrangements for the spread of the fire are found and made manifest. Several of this class of incendiaries for the insurance-money are now in prison. The saving of money alone, by the prevention of fires, would be worth the whole expense of the like arrangement in London, where it is well known that similar practices prevail extensively.

5. Is the jet used at Hamburgh for watering the streets?—Yes; the charge has been 1*d.* per foot of frontage per annum.

M. Alexis Soyer examined.

M. Alexis
Soyer.

You are known to the Commissioners from your writings on cookery; and you have doubtless had occasion to try the qualities of different waters for cooking and culinary purposes; you have probably used Thames water?—Yes, I have; when I first became cook to the Reform Club we occupied Gwydyr House, which was then supplied with Thames water.

What was your experience of it?—That it was very hard and inconvenient; it had sometimes a disagreeable taste; this, however, we found was occasioned by the cistern, which we remedied; it was, however, at all times very hard.

What was the effect of the hardness in cooking?—That we were in many processes obliged to use potass or soda for the water, to soften it.

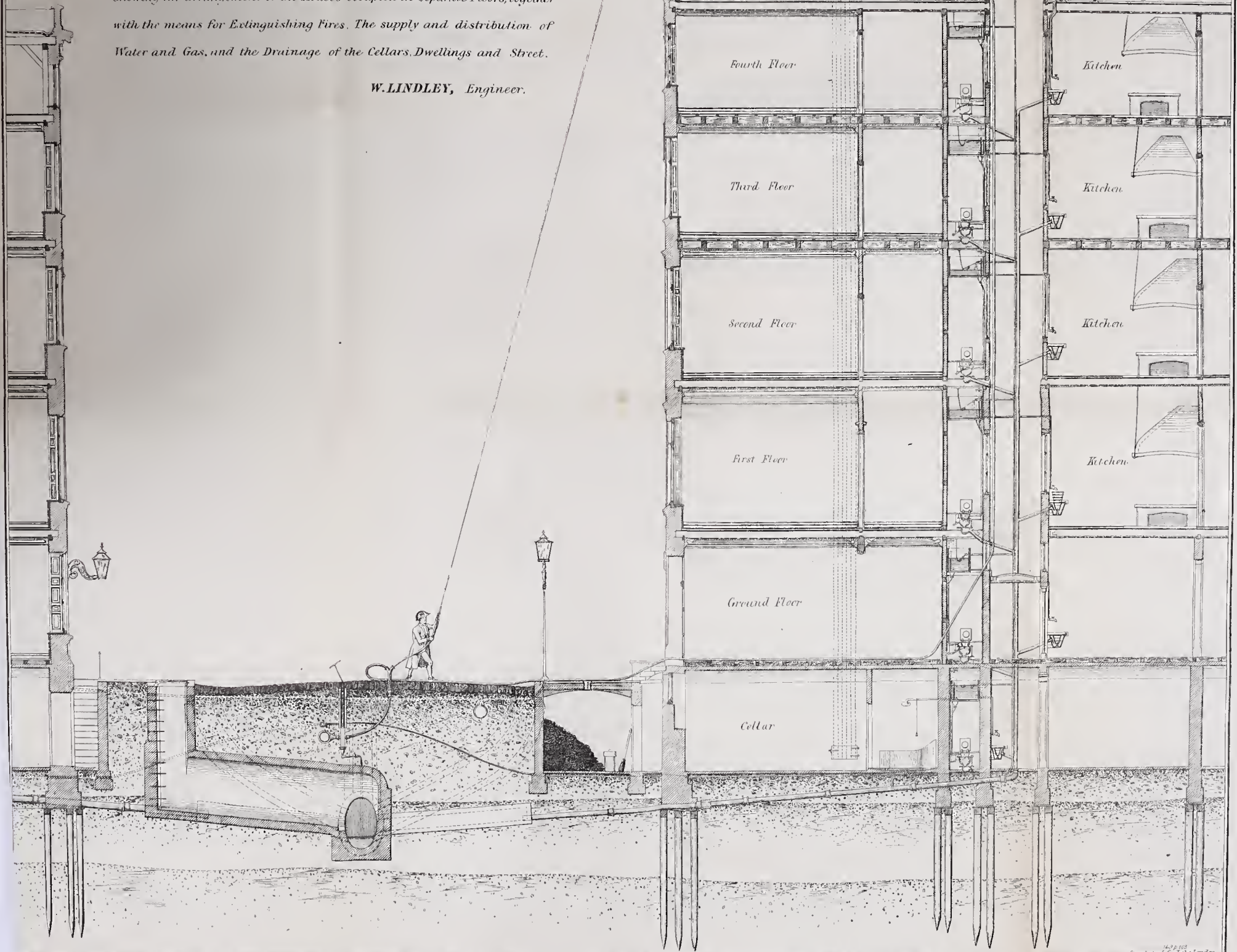
What were the processes?—First, in boiling cabbage, greens, spinach, asparagus, hard water gives them a yellow tinge, especially in French

REBUILDING OF THE CITY OF HAMBURG.

TRANSVERSE SECTION OF A STREET AS REBUILT
AFTER THE GREAT FIRE OF 1842.

Showing the arrangement of the Houses occupied in separate Floors, together
with the means for Extinguishing Fires. The supply and distribution of
Water and Gas, and the Drainage of the Cellars, Dwellings and Street.

W. LINDLEY, Engineer.



beans: hard water shrivels greens and peas, and will be more particularly noticed in French beans; the process of boiling is also longer.

That requires more fuel?—Certainly.

What would be the difference in time?—With dry vegetables certainly one-fourth more.

How is it with potatoes?—I do not think it acts so much upon potatoes, but still it has an influence upon all sorts of vegetables. I do not see the same effects however upon roots generally as upon leaves generally; the effects are very powerful.

What do you find to be the effect of hard water upon the animal foods?—Upon salt beef the hard water is not so good, it does not open the pores of the meat so freely as soft water. On fresh meat it likewise has a prejudicial effect, but not equal to that on vegetables. It has the effect of making very white meat whiter than the soft water; upon all delicate things it has however a more marked effect—for example, in making beef-tea, chicken or veal broth, or upon lamb; and the more delicate a substance is, the greater is the influence of a hard water upon it. A hard water as it were compresses the pores, whilst a soft water dilates them and the succulent matter which they contain. It makes them more nutritious. The evil of hard water is more visible in small quantities, such as broth or beef-tea.

Then it will be more prejudicial or expensive in domestic cookery, which must be in small quantities?—Exactly so; in the larger operations, where there is much boiling, the boiling itself, and for a long time, reduces the hardness. In the small quantities requisite for invalids and delicate persons the disadvantages are the most experienced. When I used Thames water at Gwydyr House, I have had quantities boiled in order to soften it, and have then let it get cool and kept it ready for use for the smaller operations.

What is the effect of hard water upon bread?—I have not had practical experience in bread-making; but there is not the least doubt that soft water is of the greatest importance as making the best bread. This is exemplified in Paris, where the water is hard, and where that bread which is made in imitation of *Gonness* bread, though made with the same flour and by the same bakers, never equals that made at the place itself, where the water is soft. I am informed that part of the water at Glasgow is very soft, and that the Scotch bakers from thence, when they first come to London, cannot understand why the bread does not rise so well as in Glasgow, even though they make use of the same yeast and flour. It is well known that the addition of a small quantity of bi-carbonate of magnesia in the water renders bread lighter and whiter.

What is your experience in respect to tea?—The hard water is injurious in deteriorating the flavour; it also requires more tea to give an equal strength. There can be no doubt that the softer water is of very great importance; we have found it so with the water used at the Reform Club, which is Artesian well water.

In respect to coffee, what is your experience?—Hard water produces a similar effect, but not quite so powerful.

[The witness was requested to obtain more particular or closer proximate results as to the comparative value of Thames and the Artesian well water in making tea, taking into account flavour as well as strength of extract.]

M. Alexis
Sayer.

Have you made the examination as to the comparative effect of waters of different qualities in the preparation of tea?—Yes, I have. In making the experiments, as time is of importance for the effect as well as for economy, I thought it proper to take an account of it. For culinary purposes I am confident that that water which boils the quickest is the best; and I conceived that this might be ascertained in respect to tea. I took samples of the common tea in use by the population, green tea and tea of a third class, and prepared them with equal quantities of water: I took, as the standard of soft water, distilled water, which I obtained from Apothecaries' Hall. The whole results were more striking than I had previously anticipated. The softest or distilled water had an extraordinary power in obtaining a quick extract; the result showed perhaps too high a power, for it draws out the woody flavour. Next to it was the Artesian well water, which is one-third less hard than the Thames water. I should indeed prefer that water to any other tried in these experiments: although the distilled water draws out the aromatic property of the tea more than the Reform Club water, it does not I think produce so good an extract. Each water gives its own shade, and had its own distinct extract. Finding the results so extraordinary, I solicited the assistance of two friends, Messrs. Hooper, the most eminent tea-tasters in London: the results were the same, and the following table gives the conclusions I came to:—(p. 233.)

Are you confident as to the difference in the time of boiling between hard and soft water?—My experiment was with pints of water, in the same size stewpan, with a gas lamp, so that the heat was manageable, and the same in both cases; and there was certainly a difference of full two minutes in favour of the boiling of the soft water; and the same result was given in several experiments.

From these experiments, and your extensive knowledge, will you state the general results as to the relative power of the hardest and the softest water in making tea?—I should say that whilst with the hard water three cups might be made, with the soft water about five might be made.

What extra expenditure of tea then would the use of the Thames water incur in making tea?—Nearly one-third.

That is on all the tea consumed in the metropolis?—Yes, I have no doubt of it.

Do you consider that the action of water in tea is a fair test and representative of its action on meat and vegetables in general, in all the delicate processes of cookery?—Yes, I do; and I have proved it in the following way. I have taken the solution of 16°, and compared it with the water from the well of the Reform Club. First, with vegetables, that is, carrots, turnips, and onions, cut into small pieces of about one inch long and an eighth of an inch square, such as are used in Jullienne soup, placed in two saucepans, with the same quantity of water, and on the same gas-stove: those cooked in the Reform water were quickly done, and the flavour of the vegetables in the water; whilst those cooked in the solution never became tender, nor did the flavour go into the water. Secondly, with potatoes: I cut a peeled potato into two, and boiled them at the same time in the above waters; the difference was easily distinguishable, that which was boiled in the hard water being harder, but at the same time whiter. Thirdly, in extracting the juice

Kinds of Water.	Time taken to boil.	Their rank in making of Tea.	REMARKS.
	Min.		
Distilled water from Apothecaries Hall	5½	2	
Covent-garden, an Artesian well*	8½	5	* Impure as if it contained iron.
Reform Club, 360 ft. deep,† and Trafalgar-square . .	6½	1	† This well has been sunk ten years; the pipes are the same as at first laid down, but they are all blistered. This makes tea one-third more than any other water.
Camden Town, sunk 200 feet in the chalk‡ . . .	8		‡ This is the well sunk by the North-Western Railway Company for the supply of their locomotives. I moved the machinery for manufacturing the nectar into Whittlebury-street, close to Euston-square Station, in order to receive the advantages of this water, and paid a large sum per annum to the Company to obtain it; but I find that the water, in passing through the iron pipes from Camden Town to the station, becomes so impregnated with iron as to cause it to be considerably altered in its nature. This fact may be seen by the deposit of iron it leaves at the urinals in the station; it likewise makes deep grooves in the pipes, as if planed out with a machine.
New River, from a cistern in Billiter-street, City . .	8	3	
Wellclose-square, a spring. . . .	10		
Camberwell, a sunk well, 60 feet deep§	10		
Thames, from Hungerford, 2 hours after high water .	9½	4	
Standard solutions of lime-water, reckoned according to Clark's scale of hardness :—			§ Camberwell is considered the hardest water in the vicinity of London.
2° 	7	6	Of the three No. 2 is by far the best.
8°	7½	7	
16°¶	8½	8	¶ Very impure, and boils with a scum upon it.

or gravy from meat: the soft water does so quickly and well, but the hard water, instead of opening the meat, seems to draw it closer together, and to solidify the gluten, and I believe that the true flavour of the meat cannot be extracted by hard water. In boiling of salt meat less salt is extracted when boiled in hard water, and at the same time the meat is not so tender as when boiled in soft water. Soft water evaporates one-third faster than hard water. I should, in every way, give the preference to soft water, but, at the same time, if very tender meat is required to boil very white, hard water should be used.

You were requested to try as completely as you could some soft water from Farnham and ascertain its value for culinary purposes, have you done so?—Yes, I have compared it on trial with between 40 and 50 specimens of different waters; some I had from Ireland, some from Scotland, and I found it the best of the whole, and very nearly of the quality of distilled water. In cooking some vegetables, however, I found the artesian well water somewhat better than the Farnham water.

M. Alexis
Soyer.

The water of the artesian well is alkaline, and that is a quality peculiarly favourable to solubility?—Yes.

As a soft water, do you find that the Farnham water has the general power which you ascribe to the softest waters—generally as compared with the river Thames water?—Yes; for, as compared with the Thames water, its power of extraction would then be as about six to four. But the flavour of the tea produced by softer water would be greatly superior.

Was the proportionate rate of boiling the same as that which you ascribe to other soft waters?—Yes; very decidedly; it boils, in the quantities I used, much quicker than the hard water.

EXTRACT from a LETTER of JOHN BULLAR, Esq.

Temple, January 24, 1850.

Mr. Bullar.

I COMPLY, as well as I can, with your request that I would give you the data on which I arrived at the conclusion that “the washing-bills of London amount to 5,000,000*l.* a-year;” premising that by “washing-bills” I mean the total cost of washing.

In the year 1844, when “The Committee for promoting the establishment of Baths and Washhouses for the Labouring Classes” was formed, it was deemed advisable to ascertain, as accurately as possible, the actual washing expenses of labouring men and their families whose washing was done at home. Inquiries were, therefore, made of several hundred families of labouring men, and it was found that, taking the wife’s labour as worth 5*s.* a-week, the total cost of washing at home, for a man and wife and four children, averaged very closely on 2*s.* 6*d.* a-week = 5*d.* a-head. The cost of coals, soda, soap, starch, blue, and sometimes water, was rather less than one-third of the amount. The time occupied was rarely less than two days, and more often extended into a third day, so that the value of the labour was rather more than two-thirds of the amount.

I may mention here that the average time occupied by a woman in washing and drying her family’s clothes at the model establishment of Baths and Washhouses, Goulston-square, Whitechapel, and the St. Martin-in-the-Fields Laundries, may be taken at about two hours and a-half, and the payment for that time, which covers the expense of coals and water, is 3*d.*; so that already (for such establishments are but in their infancy, and are capable of considerable improvements) the 2*s.* 6*d.* a-week may be considered as being reduced at least one-half to those who avail themselves of the washhouses.

In the course of the two succeeding years I made inquiries, as opportunities offered, of the cost of washing to single men among the labouring classes, whose washing expenditure might be expected to be on a very low scale, such as hod-men and street-sweepers; and I found that the lowest average weekly cost of washing to such of them as could reckon it, was 4½*d.* a-head.

I found it very difficult to ascertain the cost of washing to very small tradesmen; but I came to the conclusion, that it could not be safely estimated at much more than 6*d.* a-head a-week. Many of them maintain a position of solvency only by the narrowest economy, and it is

probable, not only that their expenditure for personal cleanliness exceeds but little, if at all, that of mere labourers, but that they have a direct personal interest in the establishment of parochial washhouses. The Rev. Sir H. R. Dukinfield, who was intimately acquainted with the condition of his (late) parish, St. Martin's, was so strongly impressed with this being the case, that he suggested the first-class washing-places for them which have been provided in that parish.

It may, perhaps, be safe to reckon the weekly washing expenses of the poorer half of the inhabitants of the metropolis as not exceeding 6*d.* a-head; but the expenditure for washing rapidly increases as the inquiry ascends into what are called "the middle classes." Among them, various sums, from 9*d.* to 1*s.* 6*d.* a-week a-head, are allowed to maid-servants for their washing, and besides that allowance, they very commonly wash at home small articles, such as caps, collars, &c., for themselves, and not, I apprehend, with any very strict regard to economy of fuel, soap, &c. The weekly allowance for washing to men-servants range, I believe, from 1*s.* to 2*s.* 6*d.* a-week, and a little washing at home is not unfrequently done for them.

It is, perhaps, safe to consider the washing expenses of the families in which those servants are employed as at double the rate of that of the servants, and, therefore, as ranging from 1*s.* 6*d.* to 5*s.* a-week a-head. In many of the wealthier families it is much higher. I have found the weekly washing-bills of young men living in chambers to range from 3*s.* 6*d.* to upwards of 10*s.* a-head.

You will easily imagine the difficulty of ascertaining with any exactness the washing expenditure of private families, and my consequent necessity of making this rough estimate. The conclusion at which I arrived was that, taking the whole population, the washing bills of London were nearly 1*s.* a-week a-head, or 5,000,000*l.* a-year. An examination of your objection that "that was half the rated rental of the metropolis," has tended to confirm me in that conclusion.

The rated rental of a house occupied by a labouring family, whose weekly washing expense is 2*s.* 6*d.*, is probably rarely equal to 5*s.* a-week. Where such a family occupy a part of a house, the proportion of that rental attributable to their rooms, or their single room, is probably decidedly less than 5*s.* a-week, except in peculiar cases. It is, therefore, not improbable that the yearly washing expenses of the poorer half of the inhabitants of London are quite equal to one-half of the rated rental of their dwellings.

The washing expenses of a middle-class family, inhabiting a house rented at 120*l.* a-year, and rated (high) at 100*l.* a-year, consisting of husband and wife, three children, and three servants, may be taken at not less than 20*s.* a-week, or more than half the rated rental; and from all that I have been able to learn, the proportion which washing expenses bear to rent is much greater in those families whose income is large enough to free them from the necessity of studying economy in matters of ordinary domestic expenditure. It is said that the average yearly value of the houses in London assessed under the income tax is 40*l.*; and that the average number of persons to every inhabited house in London is 7·4. At 1*s.* a-week a-head the washing-bills of the persons inhabiting each of those houses would be within a very small fraction of 20*l.* a-year.

Mr. Bullar.

Whether you take 1s. a-week a-head for all the inhabitants of the metropolis, or one-half of the rated rental of its houses, the washing-bills come, in round numbers, to 5,000,000*l.* a-year. Of course I give this as but a rough estimate, and many exceptions may easily be taken to it; but I feel pretty confident that it is not very far from the truth. It is some years since I worked it out, and I did so to a considerable extent from data which I have not preserved in writing; but it is, perhaps, quite as accurate as an estimate of the population of England in the reign of George II., of the total amount lost in a year in England by bad debts, of the numbers who die yearly from preventible diseases, or any other of the rough estimates which are used for statistical purposes, as not being too grossly inaccurate to be so used.

QUANTITY of WATER required for BATHS in the METROPOLIS.

Extract from a Communication by John Bullar, Esq.

MY DEAR SIR,

Putney, April 16, 1850.

The existing baths and wash-houses in London are (in the order of their opening for work),—1. Those in Glasshouse-yard, near the London Docks; 2. Those in George-street, Euston-square; 3. The model establishment, Goulston-square, Whitechapel; 4. The St. Martin-in-the-fields parochial establishment; and 5. The St. Marylebone parochial establishment. Baths and wash-houses are in course of erection or determined on, for; 6. The parishes of St. Margaret and St. John, Westminster; 7. St. James's, Piccadilly; 8. St. Giles and St. George, Bloomsbury; and 9. Greenwich. I do not include such parishes as Lambeth, where the adoption of the Act has not yet been followed up by the appointment of Commissioners to carry it into execution.

Leaving out Greenwich, as being beyond the limits of mere metropolitan water supply, and Glasshouse-yard, as being a small establishment supported as a charity for the very poor, and not reckoning plunging baths, there will probably be about 600 baths in the seven other establishments.

The greatest amount of custom that has yet been known was at the St. Martin-in-the-fields establishment, where upwards of 2000 persons bathed in one day last summer. This was at the rate of about 30 bathers to every bath. At this rate, there might be 18,000 bathers in a day in the seven establishments; and I doubt whether 30 bathers to every bath should not be considered the highest daily number that, on the average of seven or more establishments, could be reckoned on. Assuming the baths to be open from 6 A.M. till 11 P.M., with two sets of bath attendants, there might, with a regular influx of bathers, and the greatest economy of trouble given and attention paid, be as many as 50 bathers to every bath; but there are some hours in every day when there is but little custom, and a very large amount of custom requires the employment of extra attendants, who do not get through their work as expeditiously as the constant attendants.

The actual amount of water used in a bath by every bather is from 40 to 45 gallons, but an allowance has to be made for some waste, and for what is used in a steam-engine, and for cleansing the building. In

estimating for a supply, it would not be safe to reckon on having at command less than 50 gallons for every bather. Nor would it be safe to be content with having a less quantity of water at command on every day than the largest quantity that might be required on any one day, according to the season. The greatest supply is wanted in the hottest weather in summer; and if the proper amount can be had then, there will be no doubt about having enough during the rest of the year.

At 50 gallons for every bather, there ought to be the means of having, in the height of summer, a supply of not less than 900,000 gallons (about 150,000 cubic feet) of water every day.

Assuming that there will be in every wash-house as many pairs of tubs as there will be baths in the same establishment; or 600 pairs of tubs in the seven establishments; and that, on the average of the year, the wash-houses are in use 10 hours a day, the daily supply of water at command ought not to be less than 36,000 gallons (about 6,000 cubic feet) more. This is on the estimate that every washer will take two hours and a half at her work, and use 15 gallons of water.

For the sake of a margin for safety, the daily supply which the seven establishments ought to have should be about 1,000,000 gallons.

I have thus answered, as well as I can, your first question.

Your second question is not so easy to answer without appearing to run into exaggeration, and therefore I may as well premise that, when "the Committee for promoting the establishment of Baths and Wash-houses for the labouring classes" began their labours in the year 1844, the prediction that in six years there would be as many establishments of public baths and wash-houses in London, and about 30 more in other towns; and that the bathers in warm baths, chiefly of the labouring classes, in London alone, would exceed 400,000 in a year; and that not far short of a quarter of a million of pounds sterling would be expended for providing those establishments, would have been received, very generally, as utterly incredible. We may speak rather more confidently now; but still it will be advisable to imitate the prudence of Stephenson who, for fear that his evidence should be altogether discredited, did not dare to suggest to the Committee of the House of Commons on the Liverpool and Manchester Railway, that his locomotives would do more than 10 miles an hour.

I will therefore assume that the day may come when one-fourth of the inhabitants of London may like to have warm baths occasionally, and that each of them may be content with one bath a month. Taking that one-fourth at 500,000, the yearly number of baths taken would be six millions. At present, the bathing during the four warmest months is more than equal to that during the rest of the year, and at that rate, at least three million baths would be taken in twelve weeks. In round numbers, and assuming the average daily number of bathers in every bath to be 15, or one-half of the highest number, about 2,400 baths would be required for about 36,000 daily bathers, but the water supply at command ought to be sufficient (as shown above) for the highest daily number that could be expected, 72,000; and therefore the total daily quantity of water ought not to be less than 3,600,000 gallons (about 600,000 cubic feet) in addition to the quantity now required. 2,400 pairs of wash-tubs, at 60 gallons of water for each, would require 144,000 gallons (about 24,000 cubic feet) more in the daily supply.

Mr. Bullar.

Some deduction from the quantity of water required for baths has to be made on account of little children, several of whom bathe together; but, on the other hand, some addition has to be made for plunging-baths; and the two items may perhaps balance each other. We know not yet what may be done in bathing children. It would be of great good that the children in parochial and other schools should have warm baths once a week; and this might be effected without any great expense. The Committee have had under consideration a contract to bathe all the children of a large school, weekly, at 2*l.* a thousand; bathing two together in the same warm bath, and giving each a clean towel; but I doubt whether there would not be a small loss from this. 2*l.* 10*s.* a thousand would probably leave a small profit.

In answer to your third question, I should say that 50 gallons would probably be the largest quantity of water used for a single bath, and 40 gallons the smallest, reckoning waste. The Act allows four children under eight years old to bathe together, and they would not require more than 50 gallons between them.

It is but right that I should mention that the East London Water Works Company are very liberal in their charges for the water supplied to the model establishment; making a low estimate of the quantity supplied, and charging for it only half their usual rate. My estimates are, of course, higher than theirs would be; but you only ask for "proximate information," and I cannot profess to give you other than round numbers.

In multiplying the daily quantities to ascertain the year's supply, an allowance must be made for Sundays. With the sanction of the present Archbishop of Canterbury and the Bishop of London, the baths are kept open from six o'clock to half-past eight o'clock, A.M. on Sundays, so as to afford an opportunity of bathing to those labouring men whose work lasts till late on Saturday night, or who cannot be accommodated then. The pressure on a Saturday night is sometimes so great that hundreds are obliged to go away without being able to have a bath.

I have not the means of well answering your fourth question, as to the quantity of water required for the yearly washing of the clothes of every individual. It has been estimated that every woman who resorts to the wash-houses once a week washes on the average the clothes of about eight persons. This would give nearly two gallons a-week, or about 100 gallons a-year, for every person. The articles washed by her are for those whose clothes are but few; persons whose weekly washing expenditure may be about 5*d.* a-head. Taking the average weekly washing expense for the population at 1*s.* a head (according to my letter to you of January 24), and the expenditure of water for washing to be in proportion to the money expenditure for it; we should thus have about 240 gallons a-year for every person, or (reckoning the population within the limits of metropolitan water supply at two millions) an aggregate of 480,000,000 gallons (about 80,000,000 cubic feet) a-year for the metropolis. But I doubt whether this would not be much too low an estimate.

Those who now resort to the wash-houses have learned, of necessity, great economy in the use of water and soap, and it is probable that, from habit, as well as to save in soap, they use at the wash-houses little more water than they can help; but it is probable that washers who have water at command and turn into lather the soap for which

others pay (including a considerable number of those who do the work of washing at home) are much more liberal in their use of water. Wherever the supply of water is unstinted, and the disposal of it when dirty does not give much trouble, a very far larger quantity of it is likely to be used in rinsing the articles washed than can be the case among the very poor who often have to carry to and fro all the water that they need. I am, therefore, not inclined to disbelieve that the estimate which you mention of 400 gallons a-head yearly may be nearer the fact than that of 240 gallons, making the aggregate 800,000,000 gallons, (about 130,000,000 cubic feet) a year.

Mr. Bullar.

William Hawes, Esq., examined.

1. Will you state to the Commissioners what your information is as to the probable quantity of soap consumed in the Metropolis, or any proximate estimate you may have formed, and your data for the same, as to the consumption of soap by persons of the labouring classes of society?—Some years since (1844) I estimated the consumption of soap by the different classes of society with great care. The basis of the calculation was the quantity of soap charged with duty by the Excise. Careful inquiry proved that the quantity used was much greater than that indicated by the Excise returns; but reducing the results obtained by inquiry in one uniform proportion, the quantity used by the labouring classes earning from 10s. to 30s. per week is 10 lbs. each per annum, including every member of his family. Dividing the population of the Metropolis into 3 classes, the wealthy, the shopkeepers and tradesmen, labourers and the poor, and allowing 15 lbs., 10 lbs., and 4 lbs. to each respectively, the consumption of the Metropolis will be nearly 200 tons per week.

Mr. Hawes.

2. Can you estimate the probable expenditure, from any data you have, proximately or otherwise, of the population in washing?—The quantity of soap used annually in England for the purposes of cleanliness is about 55,000 or possibly 60,000 tons, but this is exclusive of the quantity supplied by illicit trade. The value of this soap, at 45l. per ton, is 2,475,000l.

3. Can you estimate the expense of washing with hard water as compared with soft?—Since the manufacture of crystals of soda at a very low price, and its almost universal use in washing, the waste of soap from washing in hard water has been very trifling. The quantity of soda used to soften water, as it is called, is a source of expense, but of a trifling amount.

4. Are you not a partner in a brewery situated near the banks of the Thames?—Yes.

5. Do you use Thames water in brewing? If not, why not?—No. I cannot say why not. Before a deep well was sunk, the brewery was supplied by the Chelsea water-works, but the supply was so irregular and the charge so high, that a well was sunk on the premises; but why this was done in preference to laying pipes to the river, I cannot say. The lower temperature of the deep well water was probably one reason, and the trouble which a supply of pure water would save in

Mr. Hawes. cleaning tanks, &c., no doubt another. But I have not heard any fault of the quality of the water supplied by the Water Company assigned as a reason for discontinuing its use.

6. What is the degree of hardness of the water you use?—The water is very soft, containing only a little carbonate of lime and soda.

7. What is the expense you incur in obtaining the separate supply of soft water for your own use?—It is difficult to say exactly. The steam-engine is always pumping. The quantity raised is about 80 gallons per minute raised to a height of 120 or 130 feet.

8. Are you aware whether there are other brewers in London who use the Thames water? If they do not, why do they not use it?—I cannot answer this question.

9. Will you state what is the difference in the solvent power of water of 2 and of 4 degrees of hardness in the extraction of the saccharine matter from a given quantity, say, a quarter of malt?—I do not know what is meant by 2 and 4 degrees of hardness; although I am not replying from actual knowledge, I should not think any water used by brewers in or near London contains sufficient earthy matter to affect its extractive power. Earthy or metallic salts would affect the fermentation of the wort no doubt.

10. As an active member of the Committee for the erection of Baths and Wash-houses, you have probably examined the expense of washing on a scale:—Will you state what it is, and any contrast which it may be in your power to give of the actual expense of separate washing by the poor?—I have no experience of the cost of washing on a large scale. The principle of the establishment for Baths and Laundries for the poor is to provide separate places for each washer. It appears to me, from the nature and condition of the linen of the poor, that it is quite impossible to wash it in bulk.

11. Have you any knowledge of the relative value of hard and soft water for making tea for culinary purposes?—No: but hard water generally becomes soft by boiling. The decreased specific gravity of the water when heated, as well as the mechanical effect of steam bubbling through it when boiling, causes many earthy salts to be precipitated. See the incrustation of earthy matter in kettles, boilers, &c.

Charles Gatliff, Esq., examined.

Mr. Gatliff,

I believe you are the Secretary to the Society for Improving the Dwellings of the Labouring Classes?—I am Secretary to the Metropolitan Association for Improving the Dwellings of the Industrious Classes.

Will you state what was the expense, in the several blocks of buildings belonging to that Society, for laying on the water?—The expense of laying on the water, including cisterns, ball-cocks, extra pipes, &c. was—

	£.	s.	d.
In the buildings of the Association in the Old Pancras- road	517	0	0
In the dwelling for single men in Albert-street, Buxton-street, Spitalfields	92	0	0
Dwellings for families, in Albert-street, aforesaid	240	15	0
	£849	15	0

How much of this was due to the cisterns?—488*l.* 10*s.*

How much would it have been in the absence of cisterns?—In the absence of cisterns alone it would have been 361*l.* 5*s.* In the absence of cisterns, ball-cocks, extra pipes, &c., it would have been 92*l.* 15*s.*, unless other arrangements were necessary, upon which I should not presume to give an opinion. Our contractors consider stronger rising mains would be necessary.

Did you make application to any of the water companies to give you a constant supply for the buildings?—Yes; I applied to the New River Company, and also to the East London Waterworks Company, through the Surveyor of the latter.

How was the application received by the Board of Directors?—The Directors of the New River Company stated that it could not be furnished, and doubted its practicability. The Surveyor of the East London Waterworks Company stated they did not furnish a constant supply from the main; that it would be always on to the ground-floor cisterns, and that the other cisterns would be filled every night.

How much will the cisterns add to the rent, including in your estimate of the rent not only the original outlay, but calculating for wear and tear and dilapidation?—The cisterns, ball-cocks, extra pipes, and wear and tear of them will amount to 2*d.* per week for each set of rooms, as near as I can calculate, the rents of which vary from 3*s.* 6*d.* to 6*s.* 6*d.* per week.

Is the water delivered unfiltered?—I should term it so, though I have understood both companies have filtering-beds.

Do the tenants filter it themselves?—I do not think they do.

Have you considered the means of filtration for these houses?—I did with regard to the dwelling-house for single men, in Albert-street, Spitalfields. I have had Mauras's filtering-machine under consideration, and hope I shall yet succeed in bringing it into operation there.

What are the obstacles to the introduction of filters?—The expense to the class of tenants sought to be benefited by this Association.

What would be the expense if you were to provide filters, and charge them to the tenants in the rent?—I should think not more than 1*d.* a week.

In respect to the supply of water, have you found the soil-pans produce as little trouble as, or even less than, common bogs or cesspools?—On two years' experience only of 110 soil-pans, in the Metropolitan Buildings, Old Pancras-road, I should say they were preferable to common bogs or cesspools, both on account of trouble, and also the facility of giving one to each family, which I think is attended with very good effects on the morals and decencies of the tenants. I have only as yet had a few weeks' experience in the dwelling for single men in Spitalfields. The houses for families there are not yet finished.

Capt. Huish.

LETTER from MARK HUISH, Esq.

*London and North Western Railway,
General Manager's Office,
Euston Station, January 9, 1850.*

SIR,

IN reply to your letter of the 3rd instant, written by direction of the Metropolitan Sanitary Commissioners, I beg to send you the following particulars of the supply of water for the use of the Railway Company.

This supply is derived from two sources; first, that required for the locomotive engines; and, secondly, that for the purposes of the offices at Euston Station, for washing carriages, the supply of the Euston and Victoria Hotels, and for the tenants of the Company's houses adjoining the Camden and Euston Stations.

First, the supply of water for locomotive engines.

This is derived from the Regent's Canal, whence the water is pumped into tanks provided for its reception. The reason for our continuing the use of the canal water will be seen in my further remarks.

Second, the supply of water for Euston Station.

This is derived from an artesian well, sunk at Camden Station two years ago. This well passes through the London clay into the chalk. The well is 9 feet 6 inches in diameter for a depth of 180 feet, where it terminates upon a cast-iron plate, in the centre of which is an aperture 12 inches in diameter, through which a bore-hole is carried down a further depth of 220 feet, the last 166 of which is in the chalk; the total depth of the well and boring is 400 feet. The water used to stand at a level of 144 feet from the surface of the ground, but it is now about 6 feet lower; whether this arises from the exhaustion of the springs, or from the bore-hole having become partially choked, is a matter which can be determined by clearing out the hole with the boring tackle.

Our engineer, Mr. Dockray, informs me that the water has been analysed, and that it contains as follows:—

					Solid Matter per Imperial Gallon.
					Grains.
Sulphate of soda	.	.	.	.	13·00
Carbonate of soda	.	.	.	.	17·60
Muriate of soda	.	.	.	.	11·10
Carbonaceous matter and traces of silica	.			.	2·30
					44·00

For household purposes this water is exceedingly good, and is in high repute with the Company's tenants.

It was originally the intention of the Company in sinking the well to derive a supply for the locomotive engines at a lower cost than they could get it from the Regent's Canal Company. It was supposed that the water would be suitable for the locomotive engines, because that obtained from the chalk at Tring and Watford was all that could be desired. On trial, however, much to our surprise, the water from the Camden well, although derived from the chalk, was found to prime so

violently as to be quite useless for locomotive purposes, without the admixture of some chemical ingredient to neutralise its alkaline properties. We were, therefore, obliged to return to the canal for the supply for this purpose. Capt. Huish.

The analysis of the waters from Tring and Watford shows that they contain only about one-half of the solid matter that the water from Camden well does, and that this matter is lime, and not soda.

The consumption of water from the well at Camden Station is 121,750 gallons per diem.

Should there be any further information which you conceive would be interesting to the Commissioners, I shall be happy to supply it; and our resident engineer (Mr. Dockray), who is a highly intelligent officer, would probably be able to give valuable information, certainly far more than I can, should the Commissioners think it desirable to examine him.

In conclusion, I may add that a very accurate account of the Camden well and of several others may be found in "Weale's Rudimentary Treatise on Well-digging and Boring."

I am, Sir,

Your obedient servant,

To the Secretary of the

Metropolitan Sanitary Commission,

Gwydyr House, Whitehall.

MARK HUISH.

William Millard, Highgate, examined.

You are head plumber in the employ of Mr. Worley of Highgate? — Mr. Millard.
I am.

How long have you been in his service?—Upwards of four years.

Mr. Worley has considerable business in the plumbing trade in Highgate and the neighbourhood, has he not?—Yes; he does the principal business here. He has carried on the trade here all his life, and his father before him; but he has lately had a paralytic seizure, and is now unable to follow his business.

Do you attend to the out-door work?—I attend solely to the plumbing work; I have nothing whatever to do with the painting.

Before you came to Highgate, had you much experience in the plumbing trade elsewhere?—Yes, in London; where I served my apprenticeship to Mr. Hatton, who was a very experienced plumber.

Have you had in the course of your business, many opportunities of observing the action of water on lead?—I have had constant opportunities of observing the action of water on leaden cisterns and pipes.

The water in Highgate is particularly hard, is it not?—I never knew a place where it was harder; it is harder in some parts of the village than in others, but altogether it is harder here than anywhere else in the neighbourhood.

You speak of the deep well-water?—Yes.

The New River Company supplies some of the houses with water?—Yes, it has done so for about five or six years.

What is the quality of the New River Company's water, as to hardness?—That also is hard; but not nearly so hard as the well-water.

Mr. Millard.

What is your observation of the different action of hard and soft water on leaden cisterns?—The hard water eats the cistern away; the soft water, that is rain water, does not sensibly touch it at all. The hard water of Highgate will, in a few years, eat the bottom of a leaden cistern entirely away, so that it will be useless.

In how many years?—In about three or four years.

Does not a leaden cistern usually last longer than that in Highgate? No; it eats holes in the bottom, particularly at the places where there is solder, giving it a honeycomb appearance. This is so much the case, that it is a common custom here for the people to have their cisterns painted.

Is that a protection?—Yes, if the paint is allowed time to get thoroughly dry before the water is let into the cistern, the water does not act upon dry lead, and the cisterns will then last for years.

What would be the appearance of a leaden cistern holding rain-water, at the end of four years?—It might be black and dirty from the settlement of filth from the roof and so on, but when it came to be scoured out and cleaned, the lead itself would be as good as new.

Have you seen many examples of this?—Yes; it is the general experience, and there is in this house an example of it. There are in this house two cisterns, one for hard and the other for soft water. The bottom of the hard water cistern is full of holes, though not quite through; but the rain water cistern is no worse for use; when I cleaned it out a short time ago, it seemed to me as good as new.

Have you observed the action of the water supplied by the New River Company on cisterns?—I have cleansed many out, and have observed that the corrosion is not half as great as in the case of the harder water. The cisterns which contain the New River Company's water, last twice as long as the well-water cisterns.

There are then in Highgate three kinds of water—a very hard water, a water of moderate hardness, and a soft or rain water—and you have had opportunities of observing the action of each kind of water on leaden cisterns and pipes?—I have, and from all my experience, I think the effect of hard water upon lead is far greater than the effect of soft water. I have always found the harder the water the quicker it eats the lead away.

Mr. William Melhuish, Plumber, &c., of 9, Bedford-street, Bedford-row, examined.

Mr.
Melhuish.

You have resided, I believe, some years in London?—I have for many years, and before that I lived in Bath and Bristol.

Have you not, in the course of your experience, found that people have of late years paid much more attention to the qualities of the water they use than they used to do?—Yes, decidedly so.

We have been informed that lead cisterns in and about London are found much worn at the bottom and sides; can you speak to this from your experience?—I have found them so worn at the bottom but not at the sides, except in some cases at Hampstead, where the water preys upon the sides and partly destroys it. I have found carbuncles stuck on it as large as my thumb.

That was hard water, I suppose?—Yes? and the water delivered at

Kentish Town is ten times worse. The Hampstead ponds, from which I think the water comes, are full of animalculæ, and especially of those with long bodies and large heads. There are, indeed, all sorts of insects in the water. I had to live in Kentish Town for two years for the sake of the health of my daughter, and I found the water there so bad that I made a contrivance by which I always procured distilled water for my use. I had a leaden vessel prepared, into which water was conveyed from the cistern, and from which a pipe conveyed the water to the boiler. From the boiler another pipe carried the steam into an outer case which surrounded the cold water vessel, and which formed, as it is termed, a double jacket to that vessel. The steam was thus condensed, and the distilled water was received into jars from a pipe communicating with the outer case of the cold water vessel. I had thus always clear pure water to drink and to use for other purposes. Comparing them, the distilled water looked like a white handkerchief, while the other was like a brown towel.

What residue was there left in the still?—When I cut it open to ascertain the effect of the water upon the lead, I found all quite clean as when first put up. I continued thus to distil the water until I left Kentish Town, owing to my daughter having recovered her health. I could always tell the difference when other than this distilled water was used for making our tea. When I was away once for a few days the still was unused, and I immediately distinguished the difference.

Did you notice how far the tea went, using soft water, compared with hard?—No, I did not; but I know that I got better tea with the distilled water. And it was so soft that you could wash your hands in it almost without soap; and the difference the use of the two waters made in the appearance of laces and caps was astonishing.

Then you thought it quite worth while to distil the water?—Yes, I continued to do so till I left the house.

Have you observed that all Thames water acts upon lead cisterns?—Yes; but in some old cisterns of 200 years of age, and which are made of very thick lead, the water has only eaten half through them, while in modern cisterns the water has eaten quite through the lead.

Is all this eating from within, or is it the action of rust, or the decay of the cistern from the outside?—No, it is the action of the water within upon the bottom.

In what time have you had cisterns thus destroyed?—In one instance, where I had as usual used lead 8 lbs. to the foot, it was, to my great surprise, eaten through in three years. I had to put a new cement bottom. That was Kentish Town water.

Have you had similar results with the Thames water?—Yes.

And with the New River water?—I have had a cistern 16 years in wear, and there are now only a few spots on the surface of the lead. That is New River water. And I conclude from this and other circumstances, that not only some water acts more on lead than other water, but that water acts more on some kinds of lead than on others; the difference resulting from the lead being brought from different parts of the country. I conceive as much difference arises from the lead-mines it comes from as from the water which is used.

Will you state an instance in which you have found that the New River water has acted upon the lead?—There was one lately, but the

Mr.
Melluish.

cistern had been in use many years. I certainly think it preys less on the lead than the Thames water. At Bromley, too, I have found the water eat through thick lead pipes in two years. That is the quickest action of water on lead I know of.

In what parts of the metropolis have you had cisterns to repair on account of the bottoms giving?—In Wandsworth, in the Southwark and Vauxhall district, and in the West Middlesex district.

Did you find much difference in the action of the water on lead in the Grand Junction district, where the water is filtered, and in the West Middlesex, where the water is not filtered?—No; and I have found the incrustation takes place quite as much from filtered New River water as from common unfiltered water.

Supposing you had a long range of buildings, and had to put cisterns to them, and used either filtered or unfiltered water, how much percentage ought fairly to be put down for dilapidations; or supposing you wanted to form a fund to cover any damage or repairs, what period do you think it would be safe to calculate the cisterns would require renewing?—I should say they would want new bottoms in 30 years, supposing the 8 lb. lead and New River unfiltered water to be used.

In the New River and other districts have you found any trace of wear in the house-service pipes when they have been taken up?—No. I have never found anything of that kind. The water does not seem to act on the pipes that merely supply it, but on the bottom of the cisterns where the water remains.

What water is that you spoke of at Bromley?—I have no doubt it was impregnated with lead; that kind of water eats away lead quicker than any other.

Did your distilled water act on the interior of the pipes?—No.

Are you aware that at the Bishop's Palace at Farnham, where they have water of not more than one degree of hardness, they have never been inconvenienced from the action of the water upon the lead?—No, I am not; but during my seven years apprenticeship in Bath, I never remember any inconvenience of the kind from the soft water which they have there, and which comes from the freestone.

You say that Kentish Town water is impure?—I think it the most impure, and the New River by far the best of the London waters.

Are there many places in London where you have put cisterns for rain water?—Yes; but rain water never acts upon the lead, and I never knew a rain water cistern that was decayed.

Then, from all your own practical experience, first, of the effects of soft water at Bath, and then of hard water in London, you would not be afraid of a supply of soft water to the metropolis?—Certainly not. I have never found any action from the water either in soft-water cisterns or pipes.

If you could get water as nearly to distilled water in purity as possible, would you not esteem it a blessing to the population?—I do not know how the apparent fact would operate that the purer the water the more it preys upon the lead.

But does not your experience, both as to rain water and the Bath water, show that pure water does not act upon the lead at all?—Certainly, I have always found that they do not.

Then it is a general impression through your trade that rain

water does not act upon lead?—I have never known it, and never heard that it acts upon lead.

Mr.
Melhuish.

Have you found that the Kentish Town water coming from the Hampstead ponds is harder than the New River water?—Yes, it is far harder. My cistern with New River water has been, as I have already said, 16 years in use, and has not been acted on at all; but I must repeat, as much depends on the quality of the lead itself, as upon the action of the water upon the lead.

William Howkins, Plumber to Mr. Short, of Kentish-town,
examined.

You perform the plumbing work for Mr. Short?—I perform all his plumbing work: no one else is employed by him in this part of his trade. I have scarcely anything to do with the painting.

Mr.
Howkins.

Have you much experience of plumbing?—I have very great experience in it; I have been with Mr. Short during the last 14 years, and he has the principal plumbing work of Kentish-town.

From what sources is Kentish-town supplied with water?—From the Hampstead ponds.

How is this water conveyed from the ponds into the houses?—By a 12-inch main pipe, with smaller pipes of 4 inches, and pipes of three-quarters of an inch to convey the water into the houses.

What are those pipes composed of?—The main and service-pipes are iron, and the smaller pipes, that is, the three-quarter inch pipes, are lead, which are soldered on to a brass funnel, by which the water is conveyed into the interior of the houses.

How often is the water laid on?—Three times a week.

How long on an average does the water continue to flow?—From three-quarters of an hour to an hour.

What are the receptacles in general use for storing the water?—Butts, and cisterns of stone, lead, and zinc.

Have you, from your own observation, found the water to exert any action on these receptacles?—The water has scarcely any perceptible action on any of these, excepting on the leaden cisterns.

What have you observed to be the action of the Hampstead pond water on leaden cisterns?—Its effect is to corrode the bottoms of the cisterns very much, making holes in them, and thus rendering them leaky, and of no service without constant repair.

How long will a new leaden cistern last without any appearance of corrosion?—About two months.

From what circumstances do you conclude that the water acts upon the cistern in so short a time?—From its leaving a white substance at the bottom of the cistern, which substance when dried becomes a powder; and if the cistern is not kept constantly cleansed, this corrosion will eat its way completely through the lead, so as to render the cistern leaky.

In general how long will it take to corrode completely through the bottom of the cistern?—It acts chiefly at the edge of the solder; if not disturbed it may not be eaten through for two or three years. The matter corroded is so hard, as to bear a hair brush pulled strongly

Mr.
Howkins.
—

over it; but when once removed, it is found that the lead is completely eaten through underneath.

Then a leaden cistern in Kentish-town does not last very long?—No, not without repairing; but if washed out constantly,—say every six weeks,—a cistern may last six or seven years. I have myself an instance of this in a cistern which I have attended to myself, and have regularly cleansed every six weeks. The bottom of this cistern has lasted to my own knowledge—for I put the bottom in myself—seven years.

It has been stated that coating the bottom of the cistern with a thick layer of paint will defend it from the action of the water. Do you think this would afford a protection?—I have had no experience of that; but I have myself made a compost consisting of bees' wax, resin, and mutton suet boiled together and spread while hot over the bottom of the cistern, which has answered effectually, having to my own knowledge succeeded in preserving a cistern eight or ten years.

But supposing no particular care were taken of a cistern, how long would it last without being corroded quite through?—That would depend on the substance of the lead.

Supposing it to be made of the ordinary substance?—We usually make it of six pounds to the square foot for Kentish-town wear.

Then suppose a cistern made of lead six pounds to the square foot, how long would this last in Kentish-town, no particular care being taken of it?—From one to two years before it would be eaten through.

Suppose a cistern made of lead exactly of the same quality and thickness, that is six pounds to the square foot, to contain rain water instead of Hampstead pond water, how long would that last without being corroded through?—The rain water would have no effect at all upon it. By mere wear it may produce some effect in twenty years, but as far as my observation may enable me to judge, it would go on year after year without any sensible effect being produced upon it. I have myself cleaned out rain-water cisterns when they have been inches deep of sediment at the bottom, consisting of all sorts of filth from the roof, and so on, but have always found them perfectly sound and free from any corrosion.

Have you had any opportunity of observing the action of lead on the service-pipes?—The earth, or the substances in the ground which may be in contact with the pipe, may perish the lead, but I have never observed any action of the water itself upon it.

This you say of the lead pipes distributing the Hampstead pond water?—Yes.

Have you had any opportunity of observing the action of rain water upon leaden pipes?—It has no action whatever upon them. I have myself taken down leaden pipes transmitting rain water for forty years, and the lead then appeared perfectly sound, presenting no appearance whatever of any action upon it.

Then as the general result of your observation and experience, you would say that hard water acts upon lead in a greater degree than soft water?—That is just what I have always observed.

Mr. Griffiths, Journeyman Plumber.

Mr. Griffiths.

Where have you worked?—Eleven or twelve years in London; at Kingston, four years.

What have you observed as to the effect of hard water on leaden cisterns?—The harder the water the more it acts on lead; the softer, the less it acts.

How does the hard water act?—In eating away the cistern. It generally eats away round the solder first, because that is the harder metal.

Do you generally find the hardest metal first acted upon?—There are various sorts of lead; I have generally observed the hardest metal first acted upon.

Do you mean the hardest metal, not at the solder, but at the surface?—Yes.

Have you ever observed the action of waters on the inside of pipes?—No, we never cut them open; I never had the curiosity to look in them to see. But we observe the action of things on the outside of pipes. Lime acts very powerfully on pipes. Thus, if we carry a lead pipe through a wall which has lime in it, the lime eats away and destroys it. Some of the clays act on the outside of lead; the yellow clay eats it away soon; we don't find the blue clays act so much upon lead pipes, but that depends upon the different parts of the country where the clay is; in some parts of the country blue clay will act on leaden pipes. In some parts of the country yellow clay does not act so much upon lead as in others.

How do you find leaden pipes affected which go on the outside of premises, and are only exposed to the action of rain, such as leaden pipes crossing areas?—I never knew any damage through rain, in my life; if there is anything the matter with them, it is generally the frost which causes it, and they are very little acted upon in the way of decay.

How do leaden gutters go?—It is generally the sun which acts upon them; it expands them and cracks them. They decay generally from beneath by old age; underneath very old leaden gutters we sometimes find the lead decayed away; it is in a white powder; we seldom find any decay on the top side.

On the whole, then, you find very little action upon lead from rain-water?—I never observed any, not a bit of difference where the water must have run over one part of the surface more than the rest.

LETTER from WILLIAM LEE, Esq.

DEAR SIR,

Sheffield, March 14th, 1848.

I HAVE been unable before now to give you the information you asked for respecting street-cleansing, &c., by the hose and jet. You will perceive that some little time was necessary in order to answer your inquiries satisfactorily. This may excuse for the delay.

Mr. Lee.

Messrs. Guest and Chrimes, of Rotherham, are patentees of a tap for the discharge of water at high pressures. They called upon me in February last, with an adaptation of their invention to the purpose of a fire plug and stand pipe, and expressed a wish to make an experiment with it.

Mr. Lee.

As their object was to show its powers to extinguish fires, we selected Church-street, one of the most public thoroughfares in the town, and containing the hall of the Corporation of Cutlers, a rather lofty building. At my request, the apparatus was applied with the most perfect success to the cleansing of the street; the Mayor, the Town Regent, and many other influential persons were present. The hose was of leather, 3 inches diameter, and about 60 yards long, with a discharge pipe $1\frac{1}{4}$ inch diameter. The carriage way is from 20 to 24 feet wide, and about 150 yards long. It was washed almost as clean as a house-floor in five minutes. The surface of the reservoir is 350 feet higher than the point of discharge, and 2557 yards distant from it. The time occupied, and the efficacy of the cleansing experiment, depended, of course, upon the quantity and force of the water, and not, to any material extent, upon the use of Messrs. Guest and Chrimes's stand pipe. The apparatus will, however, be very useful where a constant supply of water at high pressure is given, and deserves a brief description.

It consists of two parts; one of which, containing a female screw and closed valve, is to replace the common fire plug, to be fast to the main pipe, and to be covered, when not in use, by a metal cap. The other part is the stand pipe—a copper cylinder about 2 feet long, which screws on to the fire plug. On the sides of the cylinder, about 6 inches from the top, are two arms at *right angles*, and each about 4 inches long, with screws to attach the hose. A screw piston about half an inch in diameter, with crutch handle, working in a stuffing box, passes through the centre of the upright cylinder, and opens or shuts the valve of the fire plug. Its advantages are, that it can be applied to the mains, and used with great readiness, without the assistance of the turncock, at any amount of vertical pressure. With the ordinary plug it is necessary, on the discovery of a fire to seek the turncock, who is obliged, if the mains are full and a constant supply given, to seek the nearest main-tap, and turn off the water until the fire plug is opened and the hose attached, and then to go back and turn it on again. In the midst of the confusion much valuable time is thus added to that already lost in procuring the engines, and the jet is at last directed, as a matter of prudence, to the preservation of adjoining buildings, leaving that in which the fire originated to certain destruction. If this apparatus were at hand two men could have it in full operation in less than two minutes. By a slight increase in the diameter of the stand pipe, four arms might be connected with it, and four jets, managed by as many men, would throw into any building torrents of water sufficient to extinguish speedily any fire that had not been long raging.

It will be obvious that this saving of time and labour would also be of great importance as affecting the cost of any system of public cleansing by the agency of water. In consequence of the gradual opening and closing of the valve there is much less danger of bursting the hose by a sudden rush of water, or of damage to the pipes by its recoil, than with any other apparatus I have seen. The wear and tear of hose under great pressure must be a considerable item in *any* system of public cleansing. In extinguishing fires the hose is frequently burst, and before other hose can be attached, irreparable mischief is done by the raging element.

This, therefore, is a great advantage possessed by the apparatus in question.

Mr. Lee.

A serious defect in Messrs. Guest and Chrimes's invention is, that the water has to pass one right angle at the fire plug, and another at the insertion of the arm in the stand pipe. The time necessary for the discharge of a given quantity of water through a straight pipe being 1, the time for an equal quantity through a pipe of the same length and diameter, having a curve of 90° , would be 1.11, and with a right angle, 1.57. Two right angles would therefore increase the time to 2.464. As the *quantities* of water discharged in equal times by the same orifice, with the same length and form of pipes, under different pressures, are nearly as the square roots of the corresponding pressures; so, the *times* during which equal quantities of water are discharged, under the same circumstances, are nearly in the inverse ratio of the square roots of the corresponding pressures. Consequently, with the same discharge, from the same orifice *under the same vertical head*, and with a pipe of equal length and form, *a given increase of time* will indicate the amount of retardation due to any flexures, curves, or angles of the pipe. And, the retardation caused by any such flexures, curves or angles in the pipe, *will be equivalent to a certain diminution of the vertical pressure*, easily ascertained. In the experiment in question, the jet from a $1\frac{1}{4}$ inch discharge pipe with 350 feet pressure rose only to about 60 feet vertical height, in consequence of the two right angles in the apparatus.

The time for a straight pipe, being, as already stated, 1, two curved junctions would have only increased it to 1.23, while the right angle prolonged it to 2.464. The form of the pipe therefore becomes most important in any system of street-cleansing, not only as to the direct economy of time and labour, but also in reference to the power of the water in effectually removing the refuse.

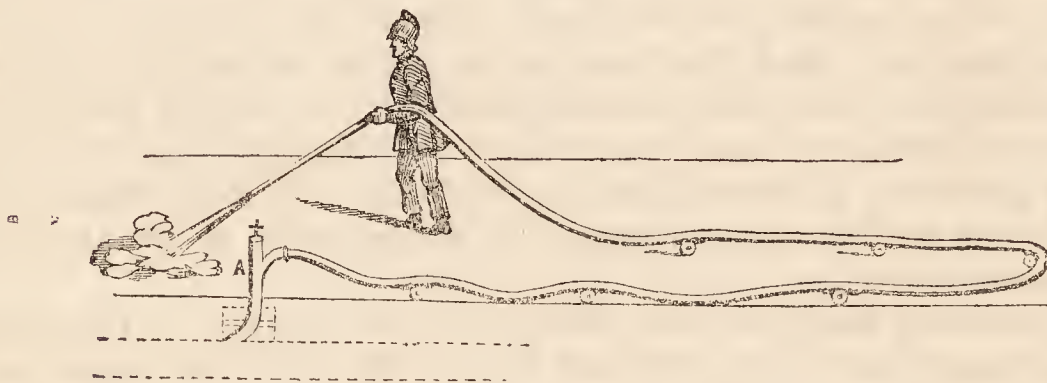
The form of the pipe is no less important when applied to the extinguishing of fires, because with curved junctions, not only will the jet rise to nearly twice the height, under the same pressure, but the hose and stand-pipe will be available without fire engines, under about half the vertical pressure necessary with right angles; and, not the least consideration is, that with an equal pressure, nearly double the quantity of water would be impelled to the same height in a given time. I suggested to Messrs. Guest and Chrimes the substitution of curved junctions, and pointed out these advantages, and am glad to hear they are about to adopt my recommendation.

Fig. 1.



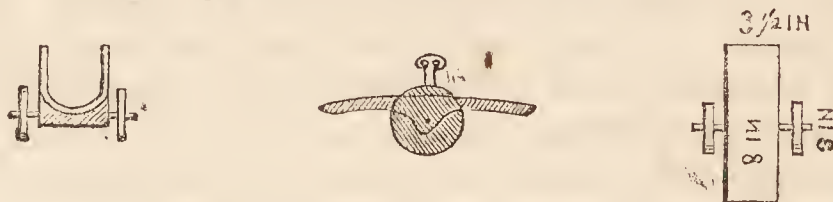
Sketch No. 1 shews the manner in which the experiment was performed, which was clumsy enough, but the best that could be adopted under the circumstances. The hose was stretched from the stand-pipe up the street, and the foreman having placed the end of the hose upon his shoulder with the discharge pipe pointing to the pavement, at a distance of about nine feet before him, the plug was opened, and he commenced walking down the street, moving the jet slightly from side to side. The weight and rush of the water through the hose was however too much for one man, and he was therefore assisted by a second, taking up the hose in a similar manner, and walking at a distance of two or three yards behind him. The work was laborious, but I have no doubt that with the substitution of curved junctions to the stand pipe, giving a greater force to the water, and the adoption of some contrivance similar to what I have figured in the sketch No. 2, the work would be done as effectually, even in less time, and with perhaps half the expenditure of physical strength.

Fig. 2.



The sketch shews a series of saddles, to be attached to the hose at regular distances, and moving on small wheels, so as to take off a great portion of the friction which has to be overcome in dragging the full hose along the pavement. The sketch will I think explain itself without further remarks, and if it is not the best thing that can be, may lead to something better from a wiser head. This sketch also shows the curved junctions for the fire plug and stand-pipe.

Plan and sections of saddles.



The third sketch shows a light carriage which would enable a man to run at great speed with the hose and all the necessary apparatus for extinguishing fires.

Fig. 3.



It is little more than a wooden drum from 18 to 24 inches in diameter, which can be made either to revolve with the wheels or to remain stationary, it would be further useful in unfolding and folding the hose without loss of time.

There would be a peg or button upon the drum, to which a loop ^{Mr. Lee.} at the end of the hose nearest the stand-pipe would be attached, and the movement of the carriage, however rapid, along the line of the hose, would wind it upon the drum. The drum would now be thrown out of gear with the wheels, and the carriage and apparatus removed to another place. On reaching its destination, it will be evident that if the drum be again put into gear with the wheels, and the carriage drawn in a contrary direction to the former, the hose will be unwound and ready to be attached to the stand-pipe without delay.

We now come to consider the quantity of water necessary for public cleansing with the hose and jet. The line of pipes leading to Church-street, used for the experiment, is 12 inches in diameter, with an area of 113·097 square inches when it leaves the reservoir. It is afterwards reduced to 9 inches, area 63·617. The hose is 3 inches, area 12·566; and the discharge pipe $1\frac{1}{4}$ inches, area 1·2271. There are branches from the main in its course, and also curves and flexures both vertical and horizontal, the sines of all which have to be accounted for, as reducing the velocity of the stream. These circumstances added to the loss caused by the right angles in the fire-plug and stand-pipe, already alluded to, very much impede the discharge. The quantity of water actually used during the five minutes was 27·19 cubic feet, or about 170 gallons. I am disposed to add half as much more for waste in emptying the hose, &c., making 255 gallons for the 150 yards of street, this is equal to 2992 gallons per mile.

I have stated that the jet was in operation for five minutes in cleansing this street. In order to make a safe estimate I allow five minutes more for unfolding and *fixing* the apparatus; five minutes for *unfixing*, &c., and five minutes for removing to the next plug, or point of operation, making altogether 20 minutes for 150 yards in length. Equal to rather more than $2\frac{1}{2}$ miles in length per day of 10 working hours. With improvement in the hose and means of transit, such as I have suggested, two men would be sufficient for one set of stand-pipe, hose and jet, and would probably execute a greater length of work.

I will now endeavour to apply the data obtained to the cleansing of a town like Sheffield. No one will doubt if two men can with ease cleanse $2\frac{1}{2}$ miles of road per day, *including the carrying away of the refuse*, that this is the most *economical* mode of street-cleansing that can be adopted, even if we leave out of consideration, entirely, the fact that the work is done more perfectly by the agency of water than by any other means. All public highways, therefore, in all large towns, ought to be cleansed with the hose and jet as a matter of economy, exclusive of sanitary considerations. Unfortunately it will be long before this is practicable in Sheffield. The roads outside the dense population are numerous, and without either pipes to convey the water, or sewers to remove the refuse. I have been compelled, therefore, to consider the question as a sanitary regulation only, and to confine my estimate to the densely populated part of the borough. The following table shows the comparative extent to which this method of public cleansing could be readily applied in the six townships which constitute the borough of Sheffield:—

Mr. Lee.

TOWNSHIP.	Total length of Public Carriage Ways.	Length to be cleansed with water three times per week.	Length to be cleansed with water twice per week.	Length to be cleansed with water once per week.	Total length of Public Highways to be cleansed with water.
	Miles.	Miles.	Miles.	Miles.	Miles.
Sheffield	31½	6	10	9	25
Ecclesall Bierlow	26¾	2	6	4	12
Brightside Bierlow	20	1	1½	1½	4
Nether Hallam	Suppose 10	1	1	1	3
Attercliff-cum-Darnall. . .	„ 3½	..	2½	½	3
Upper Hallam	„ 12	..	..	..	..
Total in the Borough .	103¾	10	21	16	47

Thus, it appears, that 47 miles, or nearly half of the public highways in the whole borough might, without difficulty, be effectually cleansed in this manner. Ten miles three times a week, equal 30 miles; 21 miles twice per week, equal 42 miles; and 16 miles once per week; making a total of 88 miles per week; or 4576 miles per annum. This at 3000 gallons of water per mile would require 13,728,000 gallons of water per annum. At *one penny* per thousand gallons, the price at which I have shown in the Report on the sanitary condition of Sheffield, an abundant supply of water could be obtained, the quantity necessary for the purpose would cost 57*l.* 4*s.* per annum.

At 6½*d.* per thousand gallons, the price obtained by the Water-works Company, the same quantity would amount to 371*l.* 16*s.* per annum.

I now proceed to the cost of labour:—4576 miles per annum is equal to 14⅔ miles for each working day, or to six sets of two men cleansing 2½ miles per day each set. To these must be added three horses and carts, and three carters, for the removal of such debris as cannot be washed away, and for such parts of the town as cannot be cleansed by this system, making a total of 15 men. Their wages I would fix at 50*l.* per annum each. Taking into account, in addition, the cost and repair of hose, horses and carts, &c., the estimate given at page 110 of the report already alluded to is correct. It is as follows:—

	£.	s.	d.
Annual interest upon the first cost of hose and pipes, three horses and carts, &c.	30	0	0
Fifteen men's wages	750	0	0
Three horses' provender	150	0	0
Wear, tear, and depreciation of hose, &c.	250	0	0
Management and incidentals, say	120	0	0
	£1,300	0	0

It is there stated that the estimate is made on the supposition that the water supply was at the public cost. I have no doubt that with the use of canvass hose, the amount allowed in the estimate for wear and tear would more than cover the 57*l.* 4*s.* required for water;—but even with this sum added, the statement in the report would not be affected,

namely, that *this would be about an average of one shilling per annum for each house in the borough.*

Mr. Lee.

The principal thoroughfares could be thus made perfectly clean, three times every week, before business hours, and the minor streets and lanes twice, or once per week, at later hours in the day; by the agency of an abundant supply of water, *at less than half the sum necessary for the cartage alone, of an equal quantity of refuse in a solid or semi-fluid condition.*

I have only to add that I have tried Merryweather's Patent Spreading Apparatus, with which you are probably acquainted, and that I think it an admirable contrivance for washing the fronts of buildings, and watering streets with the hose and jet, wherever a constant supply of water has been obtained.

I am, &c.,

WILLIAM LEE.

*Edwin Chadwick, Esq.,
Gwydyr House, Whitehall.*

LETTER FROM MR. THOMAS SPENCER.

SIR,

Liverpool, August 2, 1850.

I HAVE just seen a Report of Mr. Wicksteed's to the Corporation of Leicester on the supply of water to that borough. It contains a paper by Professors Aikin and Taylor, of Guy's Hospital, which is divided into "Remarks on the Purity of Water," and "On Dr. Clarke's Soap Test." I have so recently had the honour of laying a paper before your Board on one of those subjects, and in which I arrive at conclusions so very different from these gentlemen, that I trust to be allowed to make a few observations on their paper. At the same time I beg to assure you, Sir, that it is with great reluctance I thus venture to dissent in opinion with gentlemen of their professional standing.

Mr. Spencer.

Although my paper relates more particularly to the action of lead on various qualities of water, yet the general views of these chemists are—on this subject—so much at variance with my own, that I offer less apology for the remarks I shall make on other parts of their paper. More especially as it seems to be altogether grounded upon a passage which occurs in a report of Mr. Ranger's made to the General Board of Health in 1849 on the water-supply of Leicester. In his report this gentleman recommends the use of pure soft water in the following terms:—"The supply must be pure and wholesome,—*i. e.*, free from vegetable, animal, and mineral matter, and at the same time not flat, but well aerated." To practical men, engineers, and others, who do not profess to be chemists in the strict sense of the term, the intention and object of this passage ought, and doubtless would be, clear enough. Professors Aikin and Taylor, however, take exception to it because of its obscurity; and being at some loss, as it appears, to discover its precise meaning, they ultimately find in it an implied recommendation, by Mr. Ranger, to use "*absolutely pure*" or distilled water, or that which they tell us is the same thing, "rain water collected in clean glass vessels."

Now, I must say that this is altogether a gratuitous conversion of

Mr. Spencer. the passage, and which seems to have been made by these gentlemen for the purpose only, of recording their own opinions as to the superior wholesomeness of *hard* in contradistinction to pure *soft water*. As a proof of which they continue to say that “distilled, or rain water, collected in the manner described” (described by themselves, *not* by Mr. Ranger), “although absolutely pure, would not be proper for a diet water.” To which they add, that “this fact is well known to all professional men,” (page 82.). But a little further on they assure us, that water of this abstract degree of purity “does not exist on the surface of the globe, and that to seek for it would be needless waste of time.” Now as the last sentence quoted contains a fact, which, in its strict sense, all will be ready enough to admit—Mr. Ranger amongst others—were it not with the object of overturning it, upon what other principle do they set it up; this being a standard of purity, which, on their own showing, nowhere exists in nature, and which, it is therefore clear, could not have been intended by Mr. Ranger? Were the question to be discussed at all, it surely would have been fairer to have taken a water of such purity and softness as came within the range of ordinary circumstances to obtain.

I must confess that were I called on by a board of chemists to point out a natural site whence water might be obtained of sufficient purity for the more refined laboratory purposes, I should concur with Messrs. Aikin and Taylor that we could hardly expect to find such a natural supply; but on the other hand, had I to report to a General Board with respect to a supply of *pure* water for a town, and which should be “free from animal, vegetable, and mineral matter,” and which should also be “well aerated,” I should be at no loss to point out several places in England, where ample supplies of water, fulfilling these conditions, might be obtained. Be it observed, however, that as a chemist, I should expect to find in all of them a few grains, more or less, of mineral substance, with, perhaps, previous to filtration, a trace of vegetable matter. Still I should consider such water as being practically pure, and as such, would not hesitate so to report. The water of the upper part of Bala lake, I have found to contain little more than one grain of solid matter to the gallon, nor can it be said that it is not well aerated, or that it is flat, yet it is difficult to discover in it, more than a fractional trace of carbonates of any kind. The waters of the Millstone grit districts of Lancashire are, in this sense also, *pure waters*, and are unquestionably well aerated, yet some of them contain little more than a grain of carbonate of lime to the gallon. I might multiply such instances; but these are surely sufficient to show that pure and well aerated water may be obtained without travelling very far over “the surface of the globe.”

As to the universal opinion which we are told prevails amongst medical men as to the unwholesomeness of pure water, perhaps I may not be expected to say much. My personal experience, however, would go far to contradict it. Nor need I say to you, Sir, that it is the acknowledged opinion of a large part of that profession, that water is wholesome as a dietary water, *in proportion to its purity*. Where I have found opinions to prevail of an opposite character, they have been, not unfrequently, coupled with vague notions, that the lime contained in hard water was necessary for the structural renovation of the animal system.

Where it is so positively affirmed that pure water is an improper dietary water, surely an opinion so paradoxical ought to have been accompanied with more definite reasons, either medical or chemical. On a subject of such importance, we ought to claim not to be left in the dark; we are surely warranted in requiring this much, upon recollecting that so large a proportion of the inhabitants of the globe are somehow enabled to subsist on comparatively pure water, and which is derived not remotely from rain. Neither have I heard that any of the prevailing diseases of those countries are attributable to the freedom of the water from mineral impurity. On the other hand, I know it to be a fact, that the mineral impurities subsisting in the well or spring water, which we are at present compelled to use, does act medicinally on persons habituated to a purer water. They do not consider rain water collected on a roof as either flat or vapid; but when cool prefer it to common spring water. Instances of this description are so numerous, that it becomes specially incumbent on those who hold pure water to be so unhealthy, to instruct us not only why it is so, but also to point out the peculiar conditions which enable us to take it so largely into the system with impunity. One cannot avoid remembering, that the Malvern waters are most grateful to the palate, while they are the healthiest and *purest*, perhaps in England; their specific gravity being 1.002 or near absolute purity. The Matlock waters are little less pure, and equally healthy.

I am much at a loss to conjecture from what source Messrs. Aikin and Taylor have derived their ideas of the process by which potable spring waters become aerated in nature; these are of course entirely apart from calcareous waters so-called, which being unfit for use, are beside the question. Their explanation is to the following effect:—"Water," say they, "which is entirely free from animal, vegetable, or mineral matter—*i. e.*, distilled water, must necessarily be flat, and cannot well be aerated. The carbonate of lime constituting the greater part of the mineral matter in wholesome spring water, acts as a basis for fixing carbonic acid, and it therefore serves to aerate the water, and deprive it of that flatness which it would otherwise possess." I am much inclined to think that when framing this explanation, they had artificially aerated water only in view. I am unable to account for it on any other supposition, because, from this it would appear evident, that they intend a well aerated water, to mean, water impregnated with carbonic acid only. Although the term may have a certain degree of correctness, when applied to the refreshing draughts sold in the soda water shops of the Metropolis, yet it is obviously not the intention of the term in reference to the water supply of a town. Well aerated water, means literally, water which shall contain a due proportion of pure atmospheric air. The water of a running stream, therefore, is a well aerated water, so also is fresh fallen rain; but in neither case are they well aerated, because of carbonic acid, but they are so *only*, in virtue of the air, which they contain, constituted as we find it in the atmosphere. It is also important to bear in mind that, the purer water is, the greater its capacity to contain air; or in other words, to become well aerated, in the true sense. Suppose, however, it were considered necessary to health, to have water while in its natural state, well aerated with carbonic acid, instead of the usual proportion of pure air as found in the atmosphere, it is exceedingly difficult to comprehend how the acid is to be furnished by the process pointed out. It is true, these gentlemen inform us, that

Mr. Spencer. wholesome water ought to contain carbonate of lime, because this substance "acts as a basis for fixing carbonic acid, and therefore serves to aerate the water." But how carbonic acid can aerate water, *i. e.*, impregnate it with carbonic acid, while the *same* acid is *fixed* in the carbonate of lime, it is left for us to discover! We are also left in the dark as to the means or when it becomes liberated. Strictly speaking, carbonate of lime, as such, is never found as a *chemical* constituent of water. I am aware, however, that in what these gentlemen term "wholesome spring-water," super-carbonate of lime is often found to a large extent, and without doubt, they meant this substance, while omitting, as is not unusual, the technical prefix, it being well known that where free carbonic acid exists, carbonate of lime cannot remain even in mechanical suspension. Still the difficulty is not lessened, for should the super-carbonate give up its acid to aerate the water, its own chemical existence in the water is thereby destroyed. It might as well be said, that sulphate of soda acidulates, as that the carbonate of lime, under ordinary natural circumstances, aerates water.

This becomes obvious when it is considered that the extra equivalent of carbonic acid, which renders the simple carbonate soluble, becomes fixed as soon as it contributes to form the super-carbonate. When set free, however, *chalk is precipitated*. It is also true that the acid may be found in a state of freedom along with the super-carbonate, but then it is wholly independent of this substance, and in such a case it would be present in greater amount were the lime absent. I mention these, not so much by way of correcting mistakes or merely pointing out error, as that would hardly be in place here, but more to show the non-necessity for lime in water, even should it be to serve the purposes pointed out by these gentlemen. When it is asserted, however, that it is conducive to health to have a certain quantity of lime in water, although perhaps not highly impressed with the efficacy of the prescription, yet even then I imagine I can comprehend the prescriber. But when I am told that this lime is required for the purpose of aerating the water with carbonic acid, to prevent it from becoming flat, then, on chemical grounds, I begin to suspect some misapprehension, because *the acid which is so combined with lime can produce no aerating effect on the water*.

Where so much importance is attached to carbonic acid, it ought to be recollected by chemists that its presence in potable spring-water in no way depends on carbonate of lime. Strictly speaking, it is very much the contrary. When this acid is found in water, it is derived from rain in the first instance; the rain absorbing the acid in its descent through the atmosphere. But were there no carbonates in the stratification on which rain falls, and out of which it again springs, water would in that case contain a much larger proportion of this gaseous acid. Carbonate of lime, therefore, so far from contributing to preserve this acid, practically destroys it, by the formation of a new substance, which would appear to serve no other purpose than to render water hard. I have had to examine water which after evaporation rendered 20 grains of dry carbonate of lime to the gallon, yet at a summer temperature of 80° to 85° Faht., with delicate tests, it gave no indications of free carbonic acid.

I now arrive at the observations of Messrs. Aikin and Taylor, on the action of lead and water. The subject is treated less in detail than

might have been desired. All that can be tangibly dealt with is contained in the following passage. “There is another most serious consideration (say they) connected with the use of distilled or rain-water, namely, that in a direct ratio to its purity, or freedom from vegetable, animal, or mineral matter, it is liable to become poisoned by contact with lead, as by circulation through leaden pipes, or by being collected in leaden cisterns” (page 83.) This passage, it will be observed, is not in perfect keeping with the context, while it would appear to be mainly grounded upon experiments with lead and distilled water *only*. It will be remembered that they have already said, that water, having the purity of distilled water, nowhere “exists on the face of the globe, and that to search for it would be a needless waste of time,” while we are now informed that water of this *same purity* becomes poisoned with lead. Be it so. But the question being altogether one of practice, is it consistent or reasonable to sound a practical alarm founded on the action of a theoretical water; especially when these gentlemen admit that such water is nowhere to be found? Were it apparent, that water so pure was to be met with at every turn, then the utility of the warning might be better seen. It is said, however, that the poison becomes diffused in the *direct* ratio of the purity of the water. It is to be regretted that this is not shown by experiment, or by more detailed examples of practice with rain or slightly hard water. Those which are mentioned prove little or nothing, as, unless an exact analysis were given of the constituents of the waters with which the alleged accidents are said to have occurred, we are in the dark as to their real nature. To prove that this action is by no means in a direct ratio with the purity of the water, it may be only necessary to state, that two grains of sulphate of lime (gypsum), or half the quantity of silica, to the gallon, will do more to prevent it than ten grains of chloride of calcium or sodium (common salt). This action, therefore, cannot be said to take place in the ratio of the purity of water, unless it were shown that all waters had similar chemical constituents, and which were held in like proportions in all; and that the only difference was in the quantity held by each. But taking waters as they are usually found, *there is a point*, and that not a very high one, in the scale of mineral impurity, when this action upon lead altogether ceases.

As I have already treated of the action which ensues with very hard water when exposed to the action of air in open cisterns, I may be allowed to make a few additional observations on the action of soft water while *enclosed* in leaden service-pipes, and which are consequently free from the action of extraneous air. Cisterns, I may add, of any description are altogether incompatible with a constant supply.

It has been long known that an action will take place when *absolutely pure* water is in contact with lead. Most experimentalists agree in considering it to be the formation of a hydrated oxide of lead, which readily becomes a carbonate on exposure to air. *These substances are insoluble in pure water*, or, in other words, they are removable by filtration; a fact which, though doubted by some, is yet susceptible of easy proof. Where it appears to have failed the filter has been imperfect. Where water is caught upon a slated roof in a rural district, it is almost absolutely pure. Such water, if kept in an open cistern, would act upon *new lead*, that is, the highly comminuted powder of

Mr. Spencer. this metal would be found in the water, but *in an insoluble state*. Where circumstances render it necessary to use water of this character, where stored in a leaden cistern, or after having passed through leaden pipes, it would then be prudent to subject it to filtration. Although this process usually involves the use of cumbrous vessels, and but a tardy supply withal, yet both these inconveniences may be entirely got rid of. One of the best I have seen is "Foster's Patent Pressure Filter," which, although calculated to deliver the largest quantities, yet for domestic use need not occupy more space than the usual ball-cock of a cistern. Apart from its compactness, I have found that this filter completely arrests the passage of lead, where, for the purposes of experiment, I have caused its oxide to be mechanically diffused in water. This filter is screwed to the delivering end of the service-pipe, and there it is obvious no water need be used without having passed through it; moreover, the solid impurities which necessarily collect on the filter, are cleansed from it by the most simple yet effectual means.

With respect to the real nature of the action of water upon lead, there is ground for reasonable doubt, some assuming it to be a diffusion of particles of highly comminuted lead, which diffuse themselves in the water, while most suppose it to be the formation of an oxide. Practically, this makes little difference. Where experiments are made in open vessels, the formation of this substance is observed to be much more rapid than where the surface of the water is kept free from extraneous air; a fact which illustrates the difference of action in a closed pipe as compared with an open cistern. So far, then, with regard to *distilled water*, but the results are altogether different when made with water having one or two degrees of hardness, a water which I would term, in reference to the supply of a town, "pure soft water," *i. e.*, water as pure and soft as it is practically possible to be obtained in quantity sufficient to supply a town; such water would contain, as the case might be, 5, 6, or 7 grains of mineral impurity to the gallon. Water of this character may be had from gathering-grounds in rural but not highly cultivated districts, where lime is not a predominating ingredient in the stratification. Although a healthy pure soft water may be thus obtained, well aerated, *with pure air*, yet under such circumstances, in England it is little likely to be of that degree of purity which will act upon lead. The question, however, has now become almost beyond discussion, inasmuch as it can be resolved by the results of practice. In consequence of the growth of population and the consequent contamination of their home supplies, many towns of England and Scotland have of late years been compelled to resort to distances for purer and better water. As they have increased in population, with scarcely an exception, all large towns, both ancient and modern, have been obliged at one period or another to adopt a similar course, few of them being so fortunately situated as to render an extraneous supply unnecessary. There are at present above 20 towns in the United Kingdom with upwards of 2,000,000 of population, that are supplied with nearly pure soft water, the source of supply being, in most cases, country districts at from 4 to 10 or 20 miles distance, and which in nearly every case is constant; leaden cisterns, therefore, are not required.

What then is the nature of the experience we derive from the prac-

tice of these towns? I have made a good deal of direct inquiry, and have had information from the best sources, but have not heard of any case even of suspected indisposition which has arisen from the use of lead pipes *kept always charged with water*. On the contrary, the water itself is considered by all who have recently experienced its use as a great blessing. Such I consider to be the best answer to this unfounded alarm. I may also state that I have made experiments with several samples of soft waters procured from different localities without detecting this noxious action with lead. It is true that none of them were as free from mineral impurity as rain water, caught on a clean slated roof, but they were such waters as may be found flowing in the pure brooks of country districts in many places of the kingdom. As an example, I subjoin the results of an analysis of the water of a stream in the Rivington district of Lancashire, from whence Liverpool is about to be supplied. It fairly represents the other brooks in the same district, having examined several of them.

Carbonate of lime	.	.	.	1·300
,, magnesia	.	.	.	0·500
Chloride of sodium	.	.	.	2·150
Silica	.	.	.	0·850
Oxide of iron	.	.	.	0·200
Organic matter.	.	.	.	0·750
Grains of solid contents per gallon				<u>5·750</u>

The hardness is equal to $1\frac{1}{2}$ degrees.

This water has no action on lead, although it is very pure and very soft. Thus we see that a trifling quantity of mineral matter altogether prevents this action upon lead. I have made several experiments with other waters of different degrees of purity, with the view of determining the minimum quantity of matter in chemical solution which would altogether prevent this action. With this view I subjected the two following waters to analysis, the results of which I subjoin.

Surface Water from Red Sandstone.

			Grains.
Carbonate of lime	.	.	2·10
Chloride of sodium	.	.	1·06
Sulphate of soda	.	.	0·80
Silica	.	.	0·20
Loss and organic matter	.	.	1·03
Grains in each gallon			<u>6·09</u>

Hardness of this water, 2·4 degrees.

Water from a Brook near Bangor, Wales.

Sulphate of lime	.	.	1·40
Sulphate of magnesia	.	.	0·30
Chloride of sodium	.	.	1·40
Silica	.	.	0·20
Organic matter, loss	.	.	0·90
Grains in each gallon			<u>4·20</u>

Hardness, 1·90.

Mr. Spencer.

I should take it for granted that few would hesitate to call these pure, and soft waters, "free from animal, vegetable, and mineral matter." Yet I have kept slips of lead in them for several weeks without suffering any change; nor afterwards could lead be detected in the water; the vessel in which the experiment was made, being kept close. Purer water than this, I think, we are little likely to obtain on a large scale. But even where it contains seven or eight grains of mineral matter, with from three to four degrees of hardness, still it is to be considered comparatively a pure soft water, and most desirable for the supply of a town. But let us suppose, on the other hand, that it were possible to obtain water so absolutely pure and well aerated as to render its action on lead inevitable, surely it does not follow, that we are absolutely bound to the use of leaden pipes for its distribution, the more especially when so many substituting substances are so frequently presenting themselves. This great boon to health and domestic comfort, to say nothing of its acknowledged economy, must not be so readily given up. Our greatest cause of regret ought to be, that water of such absolute purity is not likely to be obtained.

I shall now offer a few words on Messrs. Aikin and Taylor's remarks on Dr. Clarke's soap test. Those who use this test do so only for the purpose of readily determining the quantity of soap a water decomposes before becoming detergent, and *not* as these gentlemen state, *to determine its purity*. Neither have I heard that a low degree in the scale of hardness necessarily implies a high degree of purity. I can imagine it, however, to be so considered by persons not professionally acquainted with the subject, but never by a chemist; yet we have it set down in page 87 of the Report, that "Dr. Clarke's soap test assumes to determine the purity of water by the qualities of '*hardness* and *softness*.'" Now, I think I am warranted in saying, that Messrs. Aikin and Taylor assume more than ever Dr. Clarke thought of claiming for the test, or any chemist who makes use of it. Yet these gentlemen in their remarks on the subject, speak as if all who use it, contend that *softness* according to the scale, and chemical purity, are convertible terms. It is quite true, however, that with the ordinary spring water of the south of England, where the hardness is chiefly derived from contact with calcareous earths, this test will roughly determine the mineral impurities they contain. I believe, that in the first instance, too high a degree of accuracy was claimed for the scale devised by Dr. Clarke, but this was in relation to the assumed fact, that each degree of hardness indicated the existence of a grain of carbonate of lime or chloride of calcium in the water. This however, was held to be so *irrespective of its purity or freedom from the other substances which it might contain*. But the fault which may be fairly urged is, that the scale was made with reference to salts of lime only, and that waters deriving their hardness from magnesian salts, were not taken into account. This is an important distinction no doubt, not only from the difference of the chemical equivalent of magnesia, as compared with lime, but from the different action its salts have upon soap. It followed, therefore, that in districts where the hardness of water is derived nearly as much from magnesia as it is from lime, that in those instances only, the scale is somewhat inaccurate. For my own part, I have already had occasion to point this out in a

report made to the Liverpool Corporation, of the hardness of the waters of the surrounding district. But where hardness is derived from calcareous matters, the test itself, and the scale give results very close to the truth. Even Messrs. Aikin and Taylor themselves admit, that the former method of soap testing which took distilled water for unity, was a good and ready method of arriving at comparative results, in which opinion I entirely concur. Mr. Spencer.

I have the honour to be, Sir,

Your very obedient Servant,

*Henry Austin, Esq.,
Gwydyr House, Whitehall.*

THOMAS SPENCER.

James Temple, Esq., Writer to the Signet of Paisley, examined.

What experience has there been at Paisley of the public use of waters of different qualities?—Previously to the introduction of the new water supply, the water used was spring water and river water. The spring water taken from the wells was very hard; the river water was comparatively soft, and was used for washing. A supply was afterwards obtained of yet softer water from gathering grounds, the water at present in use being of only two degrees of hardness. An Act of Parliament was obtained to supply the town with river water, as being much softer than well water, but on ascertaining that a still softer water might be procured, the townspeople allowed the Act to expire without availing themselves of the powers conferred by it. This softer water, obtained from gathering grounds, is now in use, and is of two degrees of hardness. Mr. Temple.

What can you state as evidence of popular appreciation of the softer water now supplied?—The popular complaint is that it is sold at too high a price, and they think it no crime to steal it, and they do steal it whenever they can.

May they have well water or river water without stealing?—Yes; they may.

This soft water is, then, preferred to the well or river water?—Yes; for every purpose.

For drinking?—Yes, for drinking particularly: for myself, when I come to London I think I shall not get a good drink of water until I again return to Paisley.

Is the supply of water constant at Paisley?—Yes; by gravitation.

Is the soft water considered superior for tea and washing?—For tea, there is not a lady in Paisley who would not give testimony as to its superiority. We find also in washing that we have a great saving not only of soap, but also of the wear and tear of clothes, from the greater rubbing occasioned by hard water.

Have you perceived any effect of the introduction of softer and more palatable water on the habits of the population, as respects spirit-drinking?—There is certainly less drinking among the middle and upper classes than formerly, and probably some improvement in the lower classes.

Do you know what is the general medical impression as to the effect

Mr. Templé. of the change of system?—They are unanimously in favour of the change. They all agree that calculous complaints have largely diminished since the introduction and use of the softer water. As illustrative of the public appreciation of the change, I may mention that there is now a town subscription in progress to erect a monument to Dr. Kerr, the gentleman who introduced the present soft water supply. It is considered to be a great blessing.

Dr. Shier, examined.

Dr. Shier. You are the agricultural chemist to the colony of Demerara?—Yes; I am.

Have you been led to pay special attention to the qualities of water chemically, and for its practical and domestic use?—Yes; apart from the general interest of the subject, I was led to pay special attention to it from having been present at many of the experiments made by my friend Professor Clark, of Aberdeen, in relation to the qualities of water. I was led to pay attention to the sorts of water derived from particular geological formations, and examined many waters from streams and wells on the spot.

Since you have been at Demerara, have you had experience of the use of soft water for domestic purposes?—Yes; I have. In Demerara rain water is the sort chiefly used; the water is generally gathered from the roofs of houses; these are cleaner than in England, on account of the fuel consisting of wood or of wood charcoal; hence the roof water is obtained in greater purity: then the kitchens are all to leeward, and the roofs from which the rain water is obtained are to the windward, and little influenced by the smoke. Many careful people, after a long drought, let the first washings of the roof run off by a waste pipe. The tanks are covered.

Have you yourself drank the soft rain water habitually?—Yes; I have; we all do there: thus, every member of our legislative body, when the Court is in session, has his cold water guglet and tumbler placed on the table before him along with his portfolio and writing materials.

What is your experience or observation of the use of the soft water, as compared with the hard or chalk waters?—Everybody in the colony relishes cold soft water in preference to any other sort of water, and when they go elsewhere they perceive the difference very keenly. The use of the soft water renders them very sensitive to the qualities of other waters, and they become critical in a high degree in relation to them. In Bridgetown, Barbadoes, the quality of the water which is drank by the people there without notice is hard water from the coralline formation, was found by the Demerara people to be so disagreeable, that the proprietor of one of the hotels was induced to collect and preserve the rain water for use. The consequence was, that almost all Demerarians visiting the island go to reside at that hotel. Excepting a few instances where they use soft water, I have, since I left the colony, met with no water which has seemed to me to be good, except that which I met with at New York, where the people have recently obtained a supply of soft water derived from the primary formations, at the source of the Croton

river. Here, in London, the hard water which is in use is disagreeable to me to drink, and more so to wash with, at least that which we get at the Tavistock Hotel. I find that washing with the hard London water and soap results in a sort of anointing with an insoluble lime soap.

What circumstances do you consider exercise the most important influence in rendering a drinking water palatable?—First, temperature; and secondly, purity. I think temperature of the most importance, because the purest water drank at an improper temperature will be unpalatable.

What temperature have you found the best for drinking water?—In the tropics I have found that the reduction of about four degrees below the temperature of the atmosphere is sufficient to render water palatable, and we readily attain this by putting the water in porous earthen vessels exposed in the shade to the action of the sea-breeze.

Will not low or palatable temperature disguise the qualities of water?—To an extent. If you raise the temperature of a water you will bring out, or be able to perceive, any bad qualities it may have, much more than when it is cooled; but if two waters of equal temperature be used, the one soft and the other hard, a person who has been used to the soft water will readily detect the inferior taste of hard water.

What has been your observation as to the effect of the purity of water upon health?—I think the purity of the water has a very important effect on health; although not being a medical man, my opinion may not be of great value. The only fact which I can state is, that it is well known that cases of calculus complaints do not originate in the colony. When cases of stone or gravel occur in our hospitals, they are found in patients who have come from colonies where the water is hard. This fact has been confirmed to me by several of our leading medical men. I am aware that all medical men do not connect the disease with the nature of the water; but I merely mention the fact as undoubted, that with us where we have soft water the disease does not originate or prevail, and that in the islands where they have hard water it does prevail.

Will you describe any observations you may have made on the use or choice of soft water by cattle?—I have observed that horses, mules, and cattle, decidedly prefer rain-water to all other water.

Did you ever practise Dr. Clarke's process for softening water?—Yes. I happened to arrive in the colony during a period of protracted drought, when rain-water was very scarce, and the tanks nearly exhausted. I was led by this circumstance to examine the Artesian water, of which there is a considerable supply from various borings in Georgetown, and other places in the colony. I found its principal impurity to be bicarbonate of iron, and saw at a glance that Dr. Clarke's process of purification was applicable to it. I wrote to him mentioning the circumstance, and was empowered to use his process. Owing to the weather, no opportunity occurred for using it on the large scale for a considerable time; at length, however, a dry season limited the engineer of the Demerara Railway Company to the use of bush-water and Artesian-water for the use of the locomotives. Both these waters gave much trouble from causing the engines to *prime*, and also by reason of the deposit that took place within the boilers. I was then applied to by the Directors, and had an opportunity of applying Clarke's process to the Artesian-water.

Dr. Shier.

How did you find it answer?—Admirably, Preparations were made under my directions for the use of the process on a large scale; and the purified water, which answered perfectly, continued to be used so long as the drought lasted. The process was so satisfactory, and the necessary arrangements so simple and inexpensive, that I am satisfied that when a protracted drought again occurs in the colony, Clarke's process will be used for purifying Artesian-water for the use of the poorer classes, who have no means of keeping supplies of rain-water.

Then when the rain came, the rain was preferred?—Of course it was.

There was sufficient discrimination to prefer the water of one degree, or rain-water, to the water of four degrees of hardness?—Certainly; they would not have drunk the one, whilst they could get the other, even if the water of four degrees had been of the same temperature.

Have you any information regarding the action of Demerara rain-water on lead?—Yes. My attention was first called to the subject by Dr. Blair, our Colonial Surgeon-General, in consequence of symptoms of lead-poisoning occurring in his practice. On investigation, I found lead in the suspected water, and in quantity too large to admit of a doubt of its being the cause of great and wide-spread mischief. In one case, where I operated on the water contained in a lead-cistern in a dwelling-house, I obtained as much lead, as when reduced to the metallic state, formed a globule as large as a buck-shot. In all the cases examined, the lead was in the state of an insoluble hydrate, separable by a paper, felt, or sand-filter, as in the case of Dr. Clarke's case of the water at Lord Aberdeen's marine villa. A case of *colica pictonum* occurred last year in the Colonial Laboratory, from the use of rain-water from a lead-cistern and lead service-pipes. I have no doubt that most, if not all, the cases of this disease,—and it is of too frequent occurrence in the colony,—arise from the action of the rain-water on lead. I may add, that the recent rain-water generally contains a good deal of free carbonic acid.

When you were at Aberdeen, did you hear of any lead-poisoning, or injury from the use of soft water there?—No, I do not remember any, certainly.

